The Separate System of Sewerage

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THE

SEPARATE SYSTEM

OF SEWERAGE:

ITS THEORY AND CONSTRUCTION.

BY

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NEW YORK:

D. VAN NOSTRAND,

23 MURRAY AND 27 WARREN STREETS.

1886.

H. H. EVERARD & CO.,
PRINTERS & BINDERS,
KALAMAZOO, MICH.

PREFACE.

THE subject of the sewerage of towns is attracting much more attention now than formerly. The reason for this is evident. While the country was new, and the towns small and sparsely built, the disposal of the liquid wastes and other refuse was left to be provided for by each householder as he might deem best. Various plans were employed, most of which were objectionable, and, in many cases, no plan at all. But as the towns increase in size, and are more compactly built, the question of a proper system of Sewerage forces itself upon the attention of the people. Some general system must be adopted for the whole town, and the question is, what system?

The moderate cost of the "Separate System" makes it possible to carry out a system of sewerage in many cases where the expense of the "Combined System" would make the construction of sewers impossible.

One hindrance to the rapid introduction of the Separate System has been the lack of available information concerning it. Much has been written on the subject, but the necessary information is scattered in numerous pamphlets, reports, and papers presented to scientific societies in the United States and in England.

The object of this book is to explain what the Separate System is, what it is designed to do, and to give practical directions for designing and constructing sewers in accordance with that system.

No single design, however complete in all its details, will be best adapted to every case. Each town will present some features peculiar to itself, and the general plan must be modified to suit the conditions of each case. All that is here attempted is to give sufficient theory, data, and results of experience to guide in properly designing and constructing sewers on the Separate System.

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CHAPTER I.

INTRODUCTION.

"Sanitary Engineering" has been defined as that branch of engineering which has for its object the improvement of the health of towns and districts, by bringing to them a supply of those things which promote health, and carrying from them those things which are injurious to it.

The three principal requirements for the promotion of health are wholesome food, pure water, and pure air. An abundant and cheap supply of food is best secured by perfecting the means of transportation by land and water. Pure water may be supplied by suitable water works. The air is kept pure by removing from the district those things which pollute it: that is, by removing all garbage, and by carrying out a proper system of drainage and sewerage.

Although all of these works contribute to the health of a district, yet the subdivision of labor in these times has increased the number of specialties in the engineering profession, and has limited the field of the Sanitary Engineer. By common consent the engineer who plans and executes works for improving the means for transportation is called a Civil Engineer; the engineer of a system of water works is called a Hydraulic Engineer; leaving the Sanitary Engineer the task of removing from any locality whatever may be detrimental to health; thus assigning to him the role of scientific scavenger.

In country districts, where the population is sparse, the disposal of excrementitious and refuse matter is easily managed by each householder in his own way. And even if that way be unadvisable the only sufferers are himself and those of his own household, and no one else will care to interfere. The methods usually there adopted, however, become very objectionable wherever the people congregate in large numbers. The conditions of living become changed. The sanitary condition of the immediate surroundings of each individual concerns not only himself, but the whole community in which he lives; and what was before a personal matter now becomes a question of public policy.

In all densely populated areas, as in large villages and cities, the disposal of the solid and liquid refuse becomes a serious problem. The Mosaic regulations can not be enforced, and to store the filth of a city within the city is simply to invite disease and death.

The use of the pits, dug in the earth, as receptacles for refuse, is in every way objectionable. The soil becomes polluted with sewage, and the air is filled with the noxious gases arising from the sewage soaked earth, and from the putrefying masses in vaults and cess-pools. The decomposition of so much refuse in such close proximity to the dwellings is detrimental to health in two ways. It uses up the oxygen from the air, and loads it with pestilential gases. If cess-pools are used at all, they should be water tight. This necessitates the constantly recurring trouble of carrying away the contents when they fill up, and only partly removes the difficulty.

Need of Sewerage.—An examination into the sanitary condition of a majority of our older cities and villages will show the great need of some kind of sewerage. Many of them have never taken any measures to rid themselves of the necessary accumulations of filth, incident to a considerable population. For generation after generation the refuse, which should have been removed far from the dwellings, has been flung upon the surface of the ground, or into cess-pools, where the putrefying mass poisons the air, and appeals in more ways than one for a remedy. "The offense is rank." On one of the principal streets in one of our oldest cities it became necessary to remove several small houses to erect a large building. The interior of the block

was thus exposed to view, and it simply made apparent the state of affairs in nearly every block in the city. Within the space of 150 feet long by 50 feet wide, there were four wells and seven vaults and cess-pools. It needs no chemical analysis to determine the impurity of water obtained under such circumstances, nor a very vivid imagination to conceive the foulness of the atmosphere in that locality.

The earth upon which many of our cities stand is literally saturated with sewage. The vile odors which are exhaled from the polluted soil, and from the sinks of rottenness and putrefaction which it contains, contaminate the air in the streets, and are a constant reminder of the need of an efficient remedy. There they stand, reeking in the accumulated filth of past generations, never for a day free from malaria, and zymotic diseases; and yet the remedy is easily applied and the cost of it within the reach of the poorest hamlet.

Pollution of Streams.—A small water course running through a city without sewers is sure to become a nuisance. Every conceivable variety of filth and refuse will be thrown into it, and it will soon be simply an open sewer. In dry weather, when the flow of water is at its minimum, the bed of the stream will become an elongated, open cess-pool of the worst variety. The channel is sometimes cleared by throwing the accumulations of filth upon the banks: that is, the filth is spread over a larger surface instead of being removed. Periodical cleanings of the bed and banks of the stream will only mitigate the nuisance temporarily. The cure must reach the cause of the evil if it is to be radical and entire. The sewage must be provided for in proper channels of its own, and only the storm water be allowed to run into the open water courses.

The following extracts are taken from a report of the State Board of Health of New York. The name of the city referred to is omitted, but the name of any unsewered city or village might be filled into the blank spaces and the Report would give the actual sanitary condition in a majority of cases:

"Dr. Carroll's full report on the prevalence of filth and malarial diseases in ——, and the causes thereof, is well worthy a careful reading by every citizen of ——.

"The record is both sad and alarming. Sad, because it shows that at least one-fifth of the deaths in your city during the past year were

clearly preventable by ordinary municipal provisions for cleanliness; alarming, because the already abnormal death rate from filth poisoning must, from the very nature of the cause, steadily increase. ——— affords another of the many lamentable illustrations of the apparently ineradicable popular delusion that natural water courses are the proper receptacles for sewage and house refuse of all kinds. * * It appears from the report that the number of fatal cases from diphtheria, typhoid fever, diarrhœa, and scarlet fever is, at least, three times as great as it should be under normal sanitary conditions. These diseases are known to be intensified, if not directly caused, by filth poisoning. The prevalence of malarial diseases is also reported. * * * There seems to be no doubt that there is a large amount of malarial trouble in — —. This disease is usually associated with surface or sub-soil saturation, occurring either immediately around dwellings or within such a distance that miasmatic emanations may be carried by the winds over an inhabited locality. There appear, therefore, to be at least two prominent classes of more or less preventable diseases occurring in ———, one of them dependent upon conditions of filth and the other upon undrained or saturated lands. The nature of these two classes leads to the conclusion, that filth is accumulating within the city of ——— in such a way, and in such places, as to affect the public health, and that there are saturated tracts which produce malarial diseases.

"The first and most important measure to stop the present death rate from filth diseases in ——— is to provide proper means of carrying away the organic filth of the city. The use of open brook channels as sewers should be absolutely prohibited. They should be reserved for the drainage of surface water only. Such a prohibition can hardly be made effectual until some means are provided for carrying the sewage away from the city. For this purpose a system of sewers is strongly advised, and little relief can be expected from the present unwholesome condition of the city until sewers have been built. * * *"

Pollution of Wells.—The ordinary cess-pools are especially objectionable where wells are used as a source of water supply. A well is simply a hole dug in the ground, into which the water, which has sunk into the earth, may drain. The quality of the water will depend upon the condition of the soil through which it passes. In cities without sewerage, cess-pools by hundreds are formed in the earth, into which all manner of filth is thrown. Into this same soil wells are dug, and the drippings from the cess-pools are caught and drank, and the seeds of disease are sown broadcast in the community. One often hears it said that water which passes through the earth is filtered and purified. But it must not be forgotten that the earth acts simply

as a sieve, and removes only the suspended impurities. Whatever is in solution remains in the water.

The Swiss village of Lausen, near Basle, is supplied with water from a spring, situated at the foot of a mountainous ridge, called the Stockhalden. In this village, where there had not been a single case of fever in many years, an epidemic of typhoid fever broke out, which struck down seventeen per cent. of the whole population. The cases of fever were pretty evenly distributed among the families in the village, with the exception of six. As the six families which escaped did not use water from the spring, suspicions were aroused concerning the water and investigations were made. It had previously been noticed that when the meadows in the Furlerthal—a little valley on the other side of the Stockhalden ridge—were irrigated, the volume of water in the spring was increased; and by the sinking of the soil in one of the meadows in the Furlerthal, a vein of water was discovered, which, it was supposed, led to the spring in Lausen. It was found, upon investigation, that a peasant living in the Furlerthal had returned home from a distant city, sick with fever, and that the brook in which his clothes had been washed and into which the slops from the house had been thrown, had been used to irrigate the meadows. This water thus spread out over the fields and then filtered through the ridge, a distance of a mile, still carried the germs of disease in it, and brought death to the unsuspecting inhabitants of Lausen.

To prove, conclusively, that the spring was supplied from the Furlerthal, and to determine whether the water passed through an open vein or was filtered through porous material, the following experiments were made: Several hundred weight of salt was dissolved and poured into the hole in the Furlerthal, where the vein was discovered. In a few hours the water of the spring became very salt, and the connection between the water in the Furlerthal and the spring at Lausen was established beyond a doubt.

They now mixed two and a half tons of flour in water and poured it into the hole, but no trace of the flour could be found in the spring; proving that the water was so thoroughly filtered as to remove the minutest particles of the flour, and yet it still retained its infective properties.

Clearness is no proof of purity in water. The water of the

Saratoga springs, although thoroughly impregnated with various minerals, are as clear as ordinary spring water, and in a glass of water as clear as crystal there *may* be poison enough to kill a whole family; not only by the comparatively slow and uncertain process of fever, but surely and immediately. Deleterious gases may indeed add a sparkle to well water, and the peculiar flavor so highly prized in some wells may be borrowed from a neighboring cess-pool.

Analysis of Well Water.—On opposite page is a table, showing the results of the analysis of the water supplied to Schenectady, Troy and Albany. The nitrites were reduced to nitrates, and both appear under that heading. Ammonium salts are represented by organic nitrogen. The analysis was carried on under the supervision of Prof. Perkins. The numbers represent parts per 100,000 by weight:

ANALYSIS OF WATER.

No.	Sample.	Date.	Color.	Temperature.	Permanent Hardness.	Total.	Free Ammonia.	Organic Nitrogen.	Nitrates.	Chlorine.	Remarks.
1	Schenectady W. W.	April 25	Clear	°4.4	°7.5	°11.9	None	.00300	.025619	.80	From Mohawk.
2	Troy W. W.	April 3	Clear	4.3	5.5	9.8	None	.00400	.040740	.50	
3	Albany W. W.	April 3	Clear	....	....	10.0	None	.00500	.051928	.60	From Hudson.
4	Albany W. W.	May 17	Clear	....	....	......	None	.00500	.025536	.30	From Tiv. Lake.
5	Lafayette st., Sch'y.	March 27	Clear	....	....	34.0	None	.00500	Not t'k'n	11.30	
6	Lafayette st., Sch'y.	May 31	Clear	....	....	34.0	None	.00500	Not t'k'n	12.00	
7	Lafayette st., Sch'dy	March 30	Clear	....	....	52.0	.012143	.01500	3.337003	28.40	
8	Church st., Schen'dy	April 2	Clear	....	....	......	None	.00600	4.04460	18.80	
9	Jay st., Schenectady	April 17	Clear	....	....	......	.004857	None	.84070	2.20	
10	Albany	April 19	Clear	....	....	12.7	None	None	3.65631	8.00	
11	Park Place, Schen'dy	May 31	Clear	....	....	......	None	.00700	.831503	1.50	

Let us now look at these results and see what they indicate. The total hardness of the water supplied to the three cities is about the same, the difference being no more than would exist in the same water on different days. In permanent hardness the Troy water is much better than that of Schenectady. The nitrates indicate the sewage contamination perfectly, increasing as we go down stream from Schenectady to Albany. Above Schenectady there is very little sewage flowing into the Mohawk, till we reach Utica, eighty miles above, that being the only place on the river with a system of sewers. The river itself passes over many rifts and shallows between the places, affording every opportunity for oxidation of the organic matter. At Troy the river has received the sewage of Cohoes, Waterford, Lansingburgh, etc., and at Albany that of Troy and West Troy in addition, and nitrates accordingly increase. The Hudson river water at Albany has been condemned by the Albany Water Commissioner as unfit for use, and a new source of supply has been recommended.

Samples 5 and 6 were from the same well—No. 5 taken just before it was cleaned, No. 6 about six weeks after. There is a vault a short distance from the well, with which it is evidently in direct communication, the chlorine being more in the second analysis than in the first. No. 7 was furnished by a physician of Schenectady who was called to prescribe for a man sick with typhoid fever. He suspected that the cause lay in the water, though the man affirmed that it was the best water in the city. The analysis shows, besides ammonia, organic nitrogen, and nitrates in large quantities, an amount of chlorine nearly three times as great as that in common sewage.

In No 8 the nitrates and chlorine were very high, especially the former. The well is only eighteen feet from a vault.

No. 10 was sent by a physician of Albany. He writes as follows concerning it: "I send you a specimen of well water, which I think has caused three cases of severe illness, two of which were fatal. I was called some months after these cases to see a patient who had a high fever, (temp. 105°5, pulse 140,) with diarrhœa and nausea, in whom I could find no disease of any organ to account for the fever. I stopped the use of the well water and she commenced to improve, and is now (two weeks) about well. Since I saw her she has been drinking filtered

rain water. The well in this case is within ten feet of a privy vault, and the two have adjoined one another for twenty years."

Effect of Sewerage.—The good effects of sewerage are plainly seen in the statistics of towns where an efficient system has been carried out. By sewering certain towns in England, the death rate from pulmonary diseases alone was reduced 50 per cent. A marked decrease in the amount of sickness, and a prolongation of life has always followed proper sanitary works.

Below is a table showing the results of sewerage in six towns in Great Britain:

NAME OF PLACE.	Average mortality per 1,000 before construction of sanitary works.	Average mortality per 1,000 since completion of the works.	Saving of life, per cent.	Reduction of typhoid fever, rate per cent.	Reduction in rate of pulmonary disease, per cent.
Cardiff	33.2	22.6	32	40	17
Croydod	23.7	18.6	22	64	17
Macclesfield	29.8	23.7	20	48	31
Merthyr	33.2	26.2	18	60	11
Newport	31.8	21.6	32	36	32
Salisbury	27.5	21.9	20	75	49

"At Dantzic the deaths from enteric fever per 100,000 living were as follows:

From 1865 to 1869, before any sanitary measures were taken. 108.
From 1871 to 1875, after the introduction of water supply, 90.
From 1876 to 1880, after the introduction of sewerage, 18."

The death rate in London in the last half of the 17th century was eighty in every thousand. Now it is about twenty-four in every thousand, although much more densely populated. The desirability of the removal of filth from cities is no longer a matter of doubt. The beneficial effects of a proper system of sewerage is proven by abundant statistics. The results are shown in a decrease of disease, a lowering of the death rate, and in

turning plague smitten cities into healthful ones. The question no longer is, *shall* it be done? but, *how* shall it be done?

Systems in Use.—The different systems for the removal of excrement and liquid refuse may be divided into three classes, viz.: by "Direct Removal," by the "Pneumatic System," and by "Water Carriage." Under the head of "Direct Removal," the principal methods are the "Pail System" and the "Dry Earth Closet."

In the Pail System the excreta is caught in a pail or tub and removed in carts at intervals, varying from one day to a week. This system is used in many large cities in Europe, and is advocated by eminent authorities. But the exchange and cleansing of the pails need to be enforced by such strict police regulations as would be difficult to carry out in the United States. There are several modifications of the Pail System. In one, the fluids are allowed to filter through a sieve and run off into the sewers provided for the storm water, so that only the solid matter is carried away in the carts. In another, the tub is lined with some material, which acts as an absorbent and deodorizer, as in the Goux system.

When the Dry Earth Closet is used, dry, powdered earth, or ashes, is added to the excreta in sufficient quantities to absorb the moisture and deodorize the whole mass. So much care and attention is necessary to provide a proper supply of dry earth, to apply it properly, and to attend to its removal, that it can only be used in exceptional cases, and cannot be relied upon for general use.

To obviate the difficulty of the frequent exchanges and constant supervision necessary to the successful operation of the Pail System, water-tight cess-pools are sometimes used. They are made large enough to hold the sewage for a considerable time, and when filled the sewage is carried away. The nuisance of emptying them is somewhat abated by the use of a large, air-tight iron tank, mounted on wheels. The air is exhausted from the tank, and by making a pipe connection between the interior of the tank and the sewage in the cess-pool, the contents of the cess-pool are forced by atmospheric pressure into the tank; or, the sewage may be pumped from the cess-pool into the tank.

The three principal "Pneumatic Systems" are: the "Liernur," "Berlier," and "Shone."

The Liernur and Berlier systems consist essentially of a network of air-tight iron pipes, through which the excrementitious matter is drawn, by exhausting the air from the pipes by means of large air-pumps.

These systems are intended to dispose of only that part of the household wastes which is most valuable for manure. Separate conduits must be provided for the foul liquid wastes from dwellings, factories, etc. The necessary plant and appurtenances are very expensive, and even then these systems only partly answer the purpose of sewers.

The prominent feature of the Shone System is the use of compressed air for the purpose of raising sewage from a low level to a higher one. It is especially valuable in towns where sufficient fall for sewers can not be obtained. In this plan the sewage is conducted through pipes in the ordinary way until it becomes necessary to carry it to a higher level. It then flows in to a large iron tank, called a "Pneumatic Ejector." When the Ejector is full, compressed air is automatically applied to force the sewage into pipes at a higher level, where it is again allowed to flow onward towards the outfall under the influence of gravity; or, the compressed air may be utilized to deliver the sewage from an outlet below the low water level. The air is compressed by steam, or water power, at a central station and is led by pipes to the Ejectors, so that they can be placed in any convenient situation, and as frequently as the case may require.

The Shone Ejector takes the place of a pump for raising sewage, and can be used with great advantage in situations where it would be difficult to bring the sewage to one pumping station.

All of the systems of direct removal require constant care and attention, and only partially accomplish the end in view. They are better than no system, but are not as efficient or as easily managed as the method of "water carriage" or sewerage. Water is the great scavenger. It cleanses our houses, our clothes, our food, and ourselves; and having once been soiled it must be gotten rid of. In doing this the water may be made the vehicle for carrying away excrementitious matter, which would, by putrefaction, vitiate the air and tend to produce disease.

In the Pneumatic Systems costly machinery is necessary to provide for carrying away only a portion of the refuse which

should be disposed of, and the expense of operating is large and constant.

In the Water Carriage System all that is needed is a comparatively inexpensive conduit which provides for all of the sewage; and if properly constructed the cost of maintenance is trifling.

There are many cities which have provided themselves with an abundant supply of water, and yet have made no provisions for a system of sewers. Increasing the wafer supply without providing for its outflow after it has been fouled, only makes a bad matter worse. The number and size of the cess-pools must be increased. Instead of draining the soil, as common sense would dictate, additional water is poured into it by the millions of gallons, and year by year the soil is more thoroughly soaked with sewage. The streams of filthy water which may be seen running in the open drains, leading from back yards into the streets, tell a story which all can read, and the effects of this state of affairs can be plainly seen if the Health Officer makes full reports.

One of the twelve tasks imposed upon Hercules was to cleanse the stables of Augeas. In these stables vast herds of cattle had been kept for many years, and they had never been cleaned. He accomplished the task by turning a stream of water through them. This famous exploit—"cleansing the Augeas stables"—is repeated over and over again wherever abundant water supply is supplemented by thorough sewerage. Had Hercules only planned to bring the water into the stables and made no provision for its outflow, the project would have been a miserable failure, and the sensible people of that day would have called Hercules a fool; and yet there are cities even in this enlightened age where such a plan has been pursued.

CHAPTER II.

WATER CARRIAGE SYSTEMS.

A theoretically perfect sewer would be one in which all of the sewage would be carried rapidly to its outfall outside of the city, so that no time would be given for decomposition. The conduit itself should be smooth, impervious to water, and should be water-tight throughout its entire length. It should be flushed at intervals, and so thoroughly that the development of any considerable amount of sewer gas would be impossible.

It should be so well ventilated that the small amount of sewer gas which might unavoidably be generated in the sewer would be so diluted with fresh air as to be rendered harmless.

It should be provided with ample means for inspection and repair.

It should be automatic in its action, so as to require the least possible amount of care and attention.

One of the first questions which presents itself to the engineer in planning a system of sewers is, whether the sewers shall be made large enough to carry the storm water as well as the sewage, or the sewage only. When a system of sewers is designed to carry both the storm water and the sewage, it is called the "Combined System." When the system is designed to carry only the sewage proper; that is, the liquid refuse from dwellings, factories, etc., it is called the "Separate System."

The Combined System.—The large sewers of the Combined System are usually built of brick. The brick being porous, allows more or less of the sewage to escape into the soil, even if every joint is water-tight, which is never the case. The rough surface of the bricks soon becomes covered with a slime of organic matter, which is constantly decomposing. In designing sewers on this system the size will be determined by the amount of rain-fall per hour during storms, and the surface to be drained. The volume of rainfall to be provided for is so much more than the sewage, that the amount of sewage scarcely enters into the computation.

It is readily seen that ordinarily the sewage will be but a trickling stream in a sewer large enough to carry the storm water. At the street corners are catch-basins, into which the storm water passes on its way to the sewer. Here the sand and rubbish, carried along by the current from the street, is supposed to settle and remain in the basin, while the water passes through a trap into the sewer. In the rush of water during a storm, however, a considerable quantity of the material which is supposed to remain in the catch-basin is carried on into the sewer, and this, with other foreign substances, introduced into the sewer either by accident or malice, settles on the bottom. These obstructions form a series of small dams in the sewer, and in dry weather the sewage stands in a succession of pools along the sewers, decomposing, and sending volumes of sewer gas out of every crevice through which it can escape.

The great size of the conduits of the Combined System, it is seen, is detrimental to their efficiency in removing sewage rapidly and completely; and yet, for the purposes for which they are supposed to be designed, they are seldom large enough. Even where vast sums have been spent to construct the Combined System of sewers, it is seldom, if ever, that they will carry the water of great storms. In many cities—notably Chicago and London—where money has been poured out without stint, and millions of dollars have been expended for sewers of great size, the extraordinary storms are not provided for, and the consequence is that the sewers overflow, and cellars and basements are flooded with sewage. Where the storm water is excluded from the sewers, or only a definite amount admitted for the purpose of flushing, no such disaster can occur.

The difficulties of properly flushing and ventilating large sewers are almost insurmountable. Many devices have been proposed for ventilation. Some have advocated high chimneys with a fire in them to produce a draft. Others, a shaft with a screw or fan, for producing a current. None of these plans have proved efficient, and there seems to be no way of disposing of the gas except to let it out into the street by openings from the sewer to the pavement. In any dry season, when there is the least amount of sewage and, therefore, the most sluggish flow and the greatest evolution of gas, the water evaporates from the catch-basin trap and there is nothing to hinder the escape of gas

into the streets. The catch-basin itself, unless kept clean, soon becomes a cess-pool, charged with filth from the streets and gutters, which soon decomposes.

The flushing can not be very thoroughly accomplished, owing to the rough interior surface of brick sewers, and to the large amount of water necessary in the large sewers. The most that can usually be done is to produce current enough to carry forward and out of the sewer the solid matter and rubbish, which would obstruct the flow of the sewage. Sometimes the sewage itself is stored up until a sufficient volume is collected to flush the sewer, when it is released.

These points are so well brought out in the annual report of O. W. Wight, A. M., M. D., Health Officer, Detroit, Mich., to the Common Council, that we quote quite fully from his report:

"Ditches, gutters, tiles and porous brick conduits for removing surface and subsoil water are comparatively cheap. It adds immensely to the cost to transform water drains into sewers, so as to make them at all fit to convey liquid wastes. The combined expense of a separate drainage system and an independent sewer system is much less than the expense of a single system that can not be so constructed as to perform well the double service of removing water from the soil and liquid from habitations.

"In most places it is not difficult to find a proper out-fall for the water of a drainage system. As soon as sewage is mixed with the flow of drains the whole mass is contaminated, and the trouble and cost of securing a safe out-fall are, as a rule, greatly increased. The necessity of pumping vast quantities of rain water and subsoil water, mingled with the liquid refuse of houses and factories in the same system in the new sewerage works of Berlin and Dantzic, increases the running expenses to an extent threatening failure.

"The sewage proper of a city is nearly a constant quantity. It is approximately measured by the amount of water daily used in houses and factories. Consequently, the engineer in constructing a system for the removal of sewage proper, can adapt it to a constant flow and make it self-cleansing. On the contrary, rain-fall is an immensely variable quantity. A drainage system for its removal must be of maximum size. When sewage, therefore, is turned into the drainage system, a slow flow will be inevitable much of the time, resulting in putrefaction and the generation of sewage gas, the presence of which within the area of inhabited places dangerously violates the most vital law of sanitation.

"In the drainage system all conduits are purposely made to let water in. The object is to convey water away from the soil. But a porous drain will strain sewage through into the earth, and gradually pollute it. Consequently, a conduit for the conveyance of sewage must be made

tight. Hence the absolute incompatibility of the two ends sought in the same structure. A good sewer is a bad drain. A good drain is a dangerous sewer. Attempts are constantly renewed to attain the double quality of perviousness from without and imperviousness from within, with unceasing and inevitable failure. Sanitarians who are quacks in engineering have tried it in vain; engineers who are quacks in sanitation have tried it equally in vain. Quacks in both engineering and sanitation, sometimes well represented in City Boards of Public Works, obstinately keep up their search for the unattainable, like the seekers for the philosopher's stone and the inventors of perpetual motion.

"Water stored in cisterns is almost invariably poisoned by the way of overflow pipes which discharge into the sewer system of inhabited places and return the dangerous gas. And the drain-pipes from cellars and basements generally furnish avenues through which this invisible foe of human life in cities finds easy ingress to habitations. A separate drainage system affords an easy means of guarding against peril from such a source. Sanitary inspectors are often astounded by finding a tube from an ice-box, in which choice and delicate food, like meats and milk, is kept, running directly into a sewer pipe. The combined sanitary and engineering quack will tell you, with pitiful ignorance, that the deadly sewer gas is kept out by means of a little water-trap through which a baby could blow with a straw. A separate system, used exclusively for sewage, is the only certain safety against such danger.

"With the clumsy, costly, perilous, Combined System in general use for removing water and sewage together, the earth of towns gradually becomes infected with organic matter in a state of putrescence. Hence the water of springs and wells at length becomes polluted and unfit for use. With a separate, properly constructed and properly managed system of impervious pipes for the removal of all sewage, and with other sound sanitary regulations for the care and removal of solid organic refuse, there is no reason why the spring water and well water in towns should not remain clean and wholesome. Besides, when the earth of inhabited places is kept so clean as to preserve the purity of the water, no exhalations will arise from it deleterious to health and dangerous to life.

"This is not the place to describe in detail the separate sewer systems for the removal of liquid organic wastes from inhabited places. The engineer must conform to the requirements of sanitary science. Any system will be faulty which allows sewage to putrefy at all, either in its source, on its journey from human abodes, or in its out-fall. * * * * The great principle to be kept in view is the removal of sewage (not sewage diluted with vast quanties of surface and subsoil water) without pollution of the soil, without putrefaction, and consequently without generation of sewer gas on the journey. * * * * The soil where man dwells is sacred, and it is sanitary sacrilege to pollute it. He who fouls the air that he breathes himself, or the water that he drinks, or the food that he eats, is a barbarian who might learn wisdom from the cat or

decency from any swine not demoralized by contact with man. He who fouls the air that another must breathe, or the food that another must eat, or the water that another must drink, is a criminal, to be classed with those who maim and kill.

"There are more reasons for such care in the removal of organic wastes from inhabited places than appear on the surface. The chemistry and hygiene of putrefaction are complex, involving many practical considerations. Wherever there is a collection of putrefying organic matter, whether on the ground, in the ground, within a faulty sewer, or under a habitation, there is a tireless foe to health and life. Not only are putrescent collections of garbage, decaying vegetables, manure, offal, and human excreta harmful in themselves, by reason of exhalations poisoning the air and leeching liquids polluting the earth; they are also depositories and multipliers of disease germs. Such collections may not produce infectious diseases *de novo*, but they lessen the vitality of people living in the neighborhood, and thereby lessen the power of resisting epidemics. It is a well-known pathological fact that nature struggles to eliminate disease by excretory processes. Accumulations of filth containing excreta may, therefore, harbor seeds of various communicable maladies. Sewer gas, while it may not beget scarlatina, diphtheria, smallpox, and other contagious diseases, easily becomes the vehicle of conveying them, through obscure and intricate channels. * * * A foul sewer, swarming with scarlatina germs, may be more dangerous to a neighborhood than an infected school-house. * * *

"It has been objected in relation to separate systems for drainage and the removal of sewage, that droppings of horses and other animals in the street, steeping in the rain-fall, will be a source of pollution to surface water, rendering it putrescible and, consequently, capable of generating sewer gas. The simple and effective remedy is cleaning the streets frequently and well. Most cities would thereby be greatly improved, both in appearance and salubrity.

"It has also been objected, that, in quarters where the vitrified sewer pipe system for the removal of sewage does not extend, there the inhabitants must throw the liquid wastes of household life upon the ground. No such necessity exists. Even an isolated habitation in the country should have its sewer-pipes, and entirely separate from the drainage system, to convey kitchen slops, wash-water, and other dangerous liquids to a place of safety. The reason why typhoid fever, diphtheria, and some other filth diseases are so prevalent in country districts, is that privy vaults so frequently seep into wells, and animal excreta of pig-pens and stables are left to poison the earth and the air. The ground about kitchens, super-saturated with slops, very often becomes putrescent in the summer warmth, breeding disease which superstitious ignorance attributes to Heaven. A householder may dispense with his parlor and its adornments, if necessary, but he can not afford to invite upon himself and family disease and death by neglecting to provide the means of keep-

ing the site of his habitation dry and clean. *Laborare est orare*—'to labor is to pray'—said the wise old monk, and the most effective prayer for health is to supply every needed hygienic device for the sacred home of the family.

"It is further objected that most of our cities are sewered for the double purpose of removing storm water and sewage through the same conduits, and that we cannot afford to do the costly work over again. It is one of the fates of Progress that faulty methods must be followed by reconstruction. No works last forever; and when we build anew we can do it better. In the meantime, the faulty sewers, with their dangerous debouchement into the nearest stream, lakes, or ocean harbor, can be washed out, disinfected, and used exclusively for water-drainage while a supplementary system, with safe out-fall, for the removal of sewage alone, is constructed with proper engineering skill under the direction of sanitary science. The cost of such a supplementary system is not more than one-fourth of that of the prevailing system."

Subsoil Drainage.—The benefit derived from a properly designed system of sewers is not confined to simply carrying away the sewage, but the water in the soil is drained away. In some cases special drains will need to be laid to carry off the ground water. But it will be found that simply digging the sewer trench and refilling around the pipe with sand and gravel, will make a marked difference in the condition of the surrounding soil. Especially is this the case where the soil is made up of different strata, some of which are impervious to water. Cutting through the impervious strata and partly refilling the trench with porous materials will frequently effectually drain very wet soil. It has been found in several cases where the work on sewers had been interrupted in running quicksand, that on re-opening the trench to continue the work, after a lapse of several weeks, the water had all been drained off by the trench already dug and filled, and no trouble was experienced from the water for a long distance.

CHAPTER III.

THE SEPARATE SYSTEM.

The object of the Separate System of sewers is the complete removal of the sewage proper from towns, in such a manner as shall best subserve the convenience and health of the inhabitants.

To accomplish this object in the most satisfactory manner three things are required, viz.: constant and rapid flow of the sewage; thorough flushing; and adequate ventilation.

Whatever tends to promote either of these three requirements is advantageous to the system and should be adopted. We will, therefore, consider what method of construction and combination of appliances will best attain the end in view. It is evident that to increase the size of the sewers, so as to make them large enough to carry the water of occasional storms, would be detrimental to the efficiency of the sewers, inasmuch as the ordinary flow would be impeded and retarded, and thorough flushing and ventilation made more difficult, if not impossible.

In a majority of cases the storm water can, without causing trouble, run in the surface gutters and ditches until it reaches the natural water courses. Only in large cities, where the water would need to run long distances through the streets, would any underground conduits for storm water be necessary. Where this is the case, either the sewer may be sufficiently enlarged for that purpose, or a separate channel may be provided for the storm water. The necessary length of these storm water sewers will, in any case, be but a small fraction of the whole system.

Roof Water.—On the other hand, if the introduction of a certain amount of roof water into the sewers will insure their thorough flushing whenever there is a sufficient shower, advantage should be taken of such ready means for accomplishing so desirable an end.

The object being, not the disposal of the roof water but the flushing of the sewers, no more roof water should be used than

is sufficient for that purpose; and the engineer must carefully determine at what points, and in what quantities, the roof water must be introduced.

Size and Material.—The discussion in a subsequent chapter of the amount of sewage per capita which it is necessary to provide for, and the carrying capacity of pipes, will show that the commonly received notions concerning the required size of sewers are entirely erroneous.

In a majority of cases the people's money is spent in building large sewers, when smaller ones would be more efficient and cost very much less.

Having determined the amount of sewage to be provided for, and the size of conduit necessary, the next step is to determine the material for the conduit. Up to 18 inches in diameter the best material is glazed, vitrified earthenware. It affords a smooth surface for the flow of the sewage, and is durable and cheap. Above 18 inches, sewers of brick, laid in hydraulic cement, and with a smooth coating of cement on the interior, are preferable.

Flushing.—While the problem of flushing the small sewers of the Separate System is a much less difficult one than that of flushing the large sewers of the Combined System, still the matter is of the highest importance and should receive the careful attention of the engineer. Any of the methods made use of in the Combined System can be more easily employed in the Separate System, as a much smaller quantity of water is required. With the ordinary flow of sewage in the pipes a fungus growth appears attached to the pipes beneath the flow line. This collects the sediment and slime from the sewage, and retards the flow. Even in pipes, which are apparently in good condition, a careful examination will disclose the fact that the surface of the pipe under the sewage is foul, and rapidly going from bad to worse. A rush of water will detach the fungous growth, and with it all of the filth which it has collected, and will carry it on to the out-fall.

Let any one examine a sewer which has not been flushed for several days. At first glance he will, perhaps, see nothing amiss. All seems to be in good order. But then discharge a volume of water into the sewer, sufficient to nearly fill it for

several yards. The flakes of fungus and the black, shiny clots of putrefying organic matter, which will be driven along by the rush of water, will disclose how rapidly the sewers grow foul with a quiet, even flow of sewage in them, and how essential the provision for frequent and thorough flushing.

If the rain could be relied upon to come at regular intervals, the problem of flushing would be readily solved. All that would be necessary, would be to provide for the discharge of the requisite amount of roof water into the sewers. But, unfortunately, there may be weeks without rain, and during these seasons of drought some means must be employed to supply the lack of rain water. This may be done in several ways. A flush tank mounted on wheels can be used, and this is available in towns without water works. In towns provided with water works the flushing can be done directly from the water pipes, or by means of automatic flush tanks.

Ventilation.—The ventilation of sewers has always been a difficult problem for the engineer, and especially is this the case where the Combined System is used. In the Separate System, properly constructed, and where ample provision is made for flushing, the problem is much simplified. If only fresh, running sewage is found in the sewers, and there is no place where the sewage can stagnate and decompose, there will be very little sewer gas developed. If, in addition to this, the sewers are regularly and thoroughly flushed, the air in the sewers will be so frequently changed that there is less to be feared from them on account of sewer gas, even without any special arrangement for ventilation, than from the Combined System, with the most elaborate appliances for ventilation. Besides the ventilation secured on the street lines through the man-holes, lamp-holes, and flush-tanks, a still more effective means of ventilation may be obtained by carrying the pipes of the house-drains, untrapped, up above the roofs of the houses.

We quote the following from Dr. Alfred Carpenter in the *Journal of the Society of Arts:*

"If a sewer flushes clean, as it ought to do; if it does not become the habitat of sewerage confervoid growths upon its invert; that is, if it is regularly scoured above, as well as below the line at which the sewage ordinarily runs; if there is nothing to intercept the passage of sewage

from its origin to its departure at the outlet, then there will be no sewer gas, there will be no stink, there will be no danger to anybody.

"The openings on the inverts of the arch of the street sewer will be inlets for fresh air, and the ventilators produced by the extension of the soil pipe of every water-closet above the level of the house top will be outlets for the air which has passed through the sewer. Thus a constant circulation will be promoted at all times by the ordinary laws which belong to gases, and which by their very nature prohibit stagnation in fluids of all kinds. Occasionally there may be down draughts, but they will be of no more moment than the down draughts through an ordinary chimney —indeed they will be as infrequent as a down draught into a furnace when the fire is low. Fresh sewage is not dangerous to anybody, but if it is kept within the curtilage of the dwelling-house by means of interceptors, or if it be allowed to stagnate in a badly-constructed sewer until fermentative changes have arisen within its substance, it then produces the chance of evil; but in the present day no authority ought to be allowed to keep sewage within its borders until such a change has taken place. It should be "moved on" out of range as rapidly as possible. The house is the unit of sanitary work, and it is wrong for selfishness to assert itself so as to determine that no man shall assist the local authority in its duty to provide for sewer ventilation.

"I utterly object to the principle which is being tried to be established by various supposed authorities, viz.: that the duties of the individual are antagonistic to the duties of the local authority in the matter of sewers. If each unit does his part, the duty of the local authority as to ventilation is simple. The latter has to convey away the sewage, and provide inlets for fresh air. The outlets must be at the highest points, and if they are so placed, there will not be a particle of danger from the production of sewer gas. An authority has an important duty to perform, viz.: to prevent the production of sewer air, as a major part of its work. The provision for its escape, if it does accidentally form, will be best met by details in the construction of the house drain. Concentration should not take place, and without concentration sewer gas is perfectly harmless. There will be no diffusion of enthetic germs, for they cannot live in fresh air long enough to spread infective disease, and if, perchance, a few should be discharged in the higher regions above the heads of a great or small community, they die in a very few seconds.

The germs which reproduce enthetic disease cannot live in fresh air, any more than a fish can live in unaerated water. If discharged, they should be diffused above the heads of the people, and not at the street level. These are my reasons for advocating the extension of every soil pipe, so that each water closet has a ventilator in action, and by this means properly constructed sewers will admit fresh air at the street level; and under common conditions, foul air, if produced, will escape, where it will fail to set up even the smallest possible danger. I advocated this principle twenty years ago, and experience, since my first paper upon this subject, has amply proved that I am right."

There are two methods of carrying out the plan advocated by Dr. Carpenter. One is by carrying the ventilating pipes up through the house, and the other is by carrying the ventilating pipe up on the outside of the house. Both of these plans will be considered in detail in a subsequent chapter.

Special Features.—The Separate System of sewerage is not new and untried. It has been advocated by sanitary engineers for nearly half a century, and the arguments for its adoption have been presented in many forms. It was first used in England, and has been adopted there in several towns. It is in successful operation in many towns in the United States, and is rapidly growing in popularity as it is better known and understood.

The plans employed in the different cities where it has been adopted are the same in general design, but differ in the details. The different conditions met with in the different localities would require a certain amount of variation, and each engineer has followed his own methods for solving the problems which presented themselves. The following examples will show how the plans vary in different places:

In the sewers of Memphis, Tenn., designed by Geo. E. Waring, Jr., all storm water was excluded, and a Field's flush tank was placed at the head of each branch sewer. The sewers are ventilated through the untrapped, interior house drains and ventilating pipes. Man-holes were omitted. Drain tile was laid in the same trench with the sewers.

In the sewers of Pullman, Ill., designed by Benezette Williams, C. E., the sewers are flushed by connections with the water mains, and the house drains are flushed by automatic flushing basins. Man-holes were placed 160 feet apart on the mains and 200 feet apart on the laterals.

In the sewers of Binghamton, N. Y., designed by Rudolph Hering, roof water is used for flushing, and in part of the system the sewers are made large enough to carry the storm water.

The details of the plan adopted for the sewers of Schenectady, N. Y., and the methods employed in their construction, are similar to those described in the subsequent chapters. A Van Vranken flush tank is placed at each dead end.

It is evident that the Separate System is especially applicable where, for any reason, sewage must be pumped; or where it is to be purified by any of the many processes for that purpose; or where the sewage is utilized on a sewage farm. In all of these cases the exclusion of the storm water from the sewage greatly reduces the attendant expense of the process.

Among the many advantages in favor of the Separate System, the one which appeals most strongly to the average citizen is that of reduced cost. This is the argument which reaches the heart—or, what is quite as necessary, the pocket—of the taxpayer. One of the grave objections to the Combined System is its cost. The actual cost of such systems has been from $5.00 to $10.00 per foot. The cost of the Separate System has varied from 75 cents to $2.00 per foot. It is safe to say that under ordinary circumstances its cost will be from one-eighth to one-third of that of the Combined System. Mr. W. J. McAlpine estimated the cost of a Combined System for the city of Schenectady, N. Y., at $240,000. The total cost of the Separate System now completed was about $35,000.

It may be asked why the Combined System is still adopted in so many cases, if the advantages of the Separate System are so apparent. The answer to that question is, that engineering precedent carries great weight with it among engineers, and a venerable error, even, is hard to put down. The Combined System is one of natural growth. In cities the natural water courses are covered over and converted into sewers, and branches are built leading into them. Then the branches are extended, until they form a complete system of sewers.

You can see the beginning of this system in almost any town which has a small creek running through it. The creek will be partly arched over, and branch drains will be constructed leading into it, long before the subject of sewers is brought up for consideration. When the matter does come up, the chances are that the system already begun is simply extended and completed, and another bad precedent is set, which makes the introduction of the better system more difficult.

Although local conditions and considerations of economy may in some cases make it the part of wisdom to combine storm water and house wastes in the same conduits for removal, the attainment of perfect house drainage cannot be furthered by so

doing, and quite likely will be jeopardized. Nothing interfering with the utmost attainable perfection in the sanitary condition of the drains connected with the interior of our dwellings should be allowed. If sub-surface conduits for other purposes than house drainage, and not so connected, are less perfect in their sanitary condition (and from the inconstant nature of their use they must be), it is a matter of less importance; since opening into an unconfined and widely circulating atmosphere, any noxious gases are in so much greater degree diluted and rendered innocuous.

The introduction of the Separate System marks an important era in the development of sanitary drainage, recognizing, as no other system has, the prime importance of an early removal of household and industrial wastes, which are the main factors in soil pollution. That it will best meet the requirements of all large and densely populated cities (economy considered), is not probable. That, under competent advice, it can meet the requirements of *house drainage* more perfectly in *any city* than the Combined System can not be denied. It is peculiarly adapted to many of the numerous smaller cities, which have been practically debarred from sewerage by its cost, and to outlying portions of larger ones. Its comparatively small cost permits an early and general extension, and the removal of domestic wastes before the soil has become saturated with them beyond a reasonable hope of purification.

The wide application which can be made of this system will be apparent upon an examination of the following classification of the cities and towns of the United States. The table classifies all the cities and towns of the United States of 4,000 inhabitants and upward by the number of inhabitants as given in the tenth census:

TABLE I.

Comparison of Cities in the United States by Population.

NO. OF CITIES.	POPULATION.
4	500,000 and over.
4	250,000 to 500,000
12	100,000 to 250,000
14	50,000 to 100,000
41	25,000 to 50,000
21	20,000 to 25,000
43	15,000 to 20,000
85	10,000 to 15,000
397	4,000 to 10,000

We see from an inspection of the table that about seven-eighths of the cities of the United States have less than 25,000 inhabitants, and about two-thirds less than 10,000 inhabitants. It is probable that most of these do not require a system of sub-surface removal for storm water, and that in the few remaining the system of conduits for sub-surface removal may be very limited.

CHAPTER IV.

PLANS.

In designing a system of sewers for a town, there are several things to be taken into consideration before deciding upon the plan to be adopted. The principal points to be considered are: the size of the town; its situation with reference to the disposal of sewage; the compactness of its buildings; its topography; its water supply; the character of the soil; the sanitary habits of its citizens; and its financial ability.

The amount of sewage in any town will depend upon the number of its inhabitants, their habits, and the abundance and convenience of the water supply. In a town without a public water supply the amount of sewage per head will be much less than where water is abundant. With the introduction of water works comes the multiplication of water closets, and a rapid increase in the use of water for baths and various household purposes, and the amount of sewage will rapidly increase. The volume of sewage to be provided for, in any case, may safely be taken to be equal to the volume of water used.

Sewage Disposal.—The disposal of sewage is a problem of the highest importance. When sufficient fall can be obtained the sewage is usually carried by gravity to the nearest stream, or large body of water. The effect of sewage pollution on streams and lakes is a question which is rapidly growing in importance as our population grows more dense, and more towns are sewered.

In the older countries of Europe the pollution of water courses by sewage has forced itself upon the attention of government officials, and stringent laws have been passed to protect the purity of streams. In this country the time is not far distant when the pollution of streams and lakes by sewage will need to be forbidden by law, or in many localities pure drinking water in any considerable quantities will not be obtainable.

In many cases there is no available out-fall for the sewage, and the question of its disposal comes up at once with the inception of sewer projects.

The methods for purifying sewage by chemical processes are many and various. The object of these processes is to so purify the sewage that the water may be turned into the streams. The residuum is used as a fertilizer. Wherever the right kind of land is available the sewage may be used for irrigating crops, and this has been successfully done in many cases.

Sometimes a town site is so flat that sufficient fall cannot be obtained to carry off the sewage. In this case the sewage may be pumped, or raised by Shone's System.

Storm Water.—In towns where the houses are at considerable distances apart, and no very large proportion of the surface is paved, the storm water will usually be easily disposed of without providing any underground channels for it. But in large cities, compactly built, where the greater part of the surface is paved, and where the water would need to run in the streets for long distances to reach an out-fall, provision must be made for the storm water. This may be done by enlarging part of the sewers so as to carry the surface water as well as the sewage, or by constructing special conduits for the surface water. These special conduits may, in most cases, be very much shorter than the sewers, as the storm water can be delivered into any natural water course within the town, while the sewage must be carried entirely out of the town. In every town there will problems arise peculiar to the circumstances in each case; and the details of the plan best adapted to any given requirements must be worked out to suit the conditions of that special case.

The Preliminary Survey.—Before any definite plans can be determined upon, a careful topographical survey must be made. A study of a reliable map of a town, with the heights of the street corners and points at changes of slope noted on it—or, better still, with the contour lines drawn on it—will enable the engineer to determine approximately what grades are available for the sewers; the best lines for the mains; and will enable him to so design the laterals as to lead the sewage by the most direct route to the out-fall.

These approximate calculations can then be tested by final computations made from the diagram in Chapter VI. If there are any defects in the assumptions of inclination made, it will become apparent from the diagram when the sizes are determined, and proper corrections can then be made.

It must not be forgotten, in determining the grades to be adopted, that a continuous rise along the crown of the sewer is required for the upward passage of air-currents, as well as a continuous descent along the invert for the downward flow of sewage. To accomplish this, it is necessary when the sewers flowing into a man-hole are smaller than the outflowing sewers to which they are tributary, to raise the crowns of the former slightly above that of the latter. This frequently occasions a considerable loss of grade. For example, if a man-hole having an eighteen inch outlet has a twelve inch and a ten inch sewer tributary, and to ensure a free delivery at all times we raise their crowns an inch above the crown of the outlet, the invert of the twelve inch pipe will be raised above the grade line seven inches and that of the ten inch pipe nine inches. This is illustrated in the drawing of a man-hole, Plate I. Another reason for raising the inverts of inflowing pipes at man-holes, is, that obstructions are more likely to occur at man-holes than when the sewer has its full circular section, and the increased descent thus secured tends to prevent deposits.

A preliminary survey for sewers should include such measurements as will enable the engineer to make a map of the town and profiles of the streets. The lengths and directions of the street lines should be carefully measured, and levels should be taken at every one hundred feet and at every change of slope of the surface. A datum should be selected and its distance below some well-known fixed point in the town be given. Bench marks for levels, and reference points for line should be established at every street intersection.

The establishment of bench marks should be the first step in taking the levels, and it should be done independently of the surface levels, as extreme accuracy in the final location of the grade line in construction is necessary in order that portions of the system which may be constructed separately may be properly joined. After the territory is covered with a proper system of bench marks, which have been carefully checked by cross lines and found to be correct, the surface levels can be taken very rapidly and with less care, as any error is not carried but is eliminated at the succeeding bench mark.

The transit and level notes of the preliminary survey should

be carefully preserved, after they have served their purpose in the preliminary work, as they will serve as a check on the succeeding work.

From these notes a map can be made and the contour lines drawn on it (as in the map shown in front of book), or, the height of a sufficient number of stations marked on it.

The survey should also include outlying portions of the territory which may belong to the same natural drainage basin, and for the storm water, of which it may be necessary to provide special conduits. Rough profiles of the streets can now be made, and the grade lines of the sewers laid down on the profiles. The method of determining the proper grades is fully described in the following pages, as also the method of determining the loss of elevation on curves and in the case of a smaller sewer being tributary to a larger one.

Having located the out-fall of the sewers and established its height, it will be best, in determining the grades, to work from the out-fall along the mains to the laterals, as this will show the height at which each junction must be, and what fall is available.

Capacity Required.—In designing a system of sewerage, the final question to be decided, and the most important one, is the question of size.

It is obvious that proportioning a plant to meet the demands of so inconstant and widely varying a use as the removal of storm water, presents especial difficulties, both as to economy and efficiency, and that, generally speaking, the possibilities of economical construction and service are measured by the regularity of the work.

The aggregate yearly discharge of house drainage from areas fairly built up is in excess of the entire volume of storm water that ordinarily reaches the street catch-basins. Yet the capacity required for the ample service of house drainage is, approximately, but one-fortieth of that required for, or, more properly, of that usually given to, sewers for the removal of sewage in combination with storm water from streets, gullies, roofs, paved areas, etc. In fact, though representing ultimately the greater amount of work in the Combined System of sewers, it is considered unnecessary to make house drainage a factor in computations determining their sizes. (See Adams' "Sewers and Drains for Populous Districts," page 37.)

It has, therefore, not been customary or necessary, in designing sewers of the Combined System, to investigate carefully the statistics of water consumption, either as to its quantity or the varying rate of flow at which it finally reaches the sewers. In designing a plant for the discharge of house sewage exclusively, a consideration of these questions becomes of prime importance.

Size is dependent not only on the *quantity* of sewage or of water consumed, which in ordinary cases is its measure, but upon the manner in which the water is used and the peculiar habits of the tributary population. A manufacturing district may consume and deliver to the sewers its entire quota, amounting to several hundred gallons per diem, per capita, within a few hours, while the sewage from a residence district may be distributed over the twenty-four hours at a nearly uniform rate.

The quantity of water actually used is but a small percentage of that wasted, and while the *use* of water in dwellings is intermittent, having ordinarily three maxima, the *waste* of water is more nearly constant, being caused by leaky and imperfect fixtures, or taps purposely left open to secure fresh water or to prevent freezing.

Besides the daily variations in sewage flow, there are wide variations on different days of the week, due to the varying daily habits of the people. The maximum weekly flow is ordinarily on Monday. Thus, representing the average daily flow by 100, the maximum rate of flow during an average day may be 150, and Monday having in addition to these fluctuations those peculiar to itself, may have a maximum rate of flow one-third greater, which would be represented by 200; and since the sewers must be proportioned to discharge the maximum flow occurring at any hour during the week, in this case it should be made to carry twice the average daily flow.

Changes of Temperature.—There are also wide variations in water consumption and consequently in sewage flow, due to climatic differences and variations in temperature, which are usually too little considered in proportioning the size of sewers, and particularly of main sewers.

In a majority of our cities, the maximum consumption of water occurs during the winter months, and as it is due to water taps which are left open to prevent freezing, a greater percent-

age of the total consumption than in ordinary cases reaches the sewers, and the maximum rate of water consumption becomes in still greater degree the maximum rate of sewage flow. The secondary maximum of water consumption, occurring in summer, is in greater degree used for purposes which withdraw it from the sewers, as in street and lawn sprinkling, etc.

It is during this maximum rate of flow, occurring in the winter months, that sewers are more likely to be surcharged than at any other time, and it should be carefully considered in proportioning the sizes of pipes in the system. It is true that it is the result of a waste of water, which is perhaps extravagant, and which it might be better economy to check than to remove by sewerage.

Use of Water Increasing.—It is also true that the per capita consumption and waste of water has been gradually increasing up to the present time, and is likely to reach still higher figures. This increased demand for water has been met by pumping engines of much higher duty, and by improvements in water works generally, which enable them to furnish water to the consumer at lower and lower rates per gallon, commensurate with the increased economy secured. This, in turn, encourages the use of water from the public mains for motive power, as the running of elevators, motors, etc., and for the thousand and one purposes of light manufacturing, requiring the use of power, always ready, and costing nothing when not wanted. The application of water under pressure as a motive power to work of this class is apparently in its infancy, and is destined within the probable life of sewerage systems now contemplated to considerably augment their flow. Rapid as has been the development of water supply systems in the United States, their capacity has barely kept up with the demands of the people.

CHAPTER V.

QUANTITY OF SEWAGE.

Owing to the scarcity and incompleteness of data at present accessible on the actual flow of sewers, and to their unreliability as well, and to the very complete records of water consumption, which are made possible by the use of pumping machinery, automatically recording its own performances, an investigation and classification of the statistics of water consumption will, undoubtedly, be of use in designing a sewerage system. Size is entirely a matter of calculation from data, mainly assumed, as:

(1) The extent of the system.

(2) The density of population, or the probable density of population in the near future.

(3) The number of gallons of sewerage per diem per capita.

(4) The varying rates of sewage discharge.

(5) The inclination of the sewers.

(6) The smoothness of the interior surfaces of the sewers.

Of the above factors entering into calculations determining size, those of extent and inclination only are capable of exact determination. And since in designing a system of sewerage for American towns, the element of future growth must be considered, not only by increased density of population, but by the extension of the suburbs, thus extending the dead ends, and practically converting what was formerly a lateral into a main, the factor of extent may be considered to have an element of uncertainty.

Upon the accuracy of the assumption made by the engineer, then, in regard to these variable factors entering so largely into his calculations, will the efficiency of the system mainly depend.

The following statistics of water consumption are given with a view of showing what may be a proper value for each of these variable factors in ordinary cases. They have been collected from various sources, and a summary is presented in condensed tabular form, convenient for reference. A few statistics of sew-

age discharge are also presented, but, owing to the difficulties previously stated, they indicate the condition of sewage flow for a very brief period only, and admit of but limited application. When examined in connection with the statistics of water consumption they are of increased interest.

The consumption of water will be examined in the following manner:

(1) The quantity of water consumed.
(2) Monthly variations.
(3) Daily variations.
(4) Hourly variations.
(5) Variations due to extremes of temperature.
(6) Special cases—as, cities using water largely in manufacturing, brewing, etc.

In the following tables the standard of comparison taken is the average per diem per capita consumption, which is, for purposes of comparison, assumed at 100, and from statistical data the per cent. comparison is made by computation, as this is most convenient for use.

The average per diem per capita consumption is that most readily obtained, especially from pumping records of the smaller cities, in which records are usually less perfect, being computed from automatic counter readings. In many records of pumping works, where the supply is compared with the population, the results are misleading. For instance: in the smaller cities of from 10,000 to 15,000 inhabitants, while the per diem per capita consumption, based on the total population, is but little below the average, the actual per diem per capita consumption for each person using water from the city mains must be greatly above the average, as the proportionate number of consumers in such cities is frequently below one-half, and, consequently, the sewage flow in proportion to the actual tributary population is disproportionately large. This condition is, undoubtedly, owing to the usual laxity of cities of this class in controlling the use of water, and is corrected as the city increases in population and improves in its conduct of municipal affairs.

The water statistics of large cities are often misleading in the other direction, many supplying water from the city mains to their own entire population, and to outlying suburban dis-

tricts as well, which, in many cases, is not stated in published reports. In many cases, also, the per capita consumption in published returns is based upon estimates of population, which are merely guesses and may be wide of the mark.

The sewerage of every city presents problems for solution essentially peculiar to itself, and these must be carefully considered. The tables here given, while not strictly applicable to certain special cases, will, nevertheless, be a guide in determining their requirements.

The Quantity of Water Required.—The following is J. T. Fanning's estimate for American cities:*

"In American cities having well arranged and maintained systems of water supply, and furnishing good, wholesome water for domestic use, and clean, soft water adapted to the uses of the arts and for mechanical purposes, the average consumption is found to be approximately as follows:

(*a*) For ordinary domestic use, not including hose use: 20 gallons per capita per day.

(*b*) For private stables, including carriage washing, when reckoned on the basis of inhabitants: 3 gallons per capita per day.

(*c*) For commercial and manufacturing purposes: 5 to 15 gallons per capita per day.

(*d*) For fountains, drinking and ornamental: 3 to 10 gallons per capita per day.

(*e*) For fire purposes: 1 to 10 gallons per capita per day.

(*f*) For private hose, sprinkling streets and yards: 10 gallons per capita per day during the four driest months of the year.

(*g*) Waste, to prevent freezing of water in service pipes and house fixtures in northern cities: 10 gallons per capita per day during the three coldest months of the year.

(*h*) Waste, by leakage of fixtures and pipes, and use for flushing purposes: from 5 gallons per capita per day, upward.

The above estimates are on the basis of the total population of municipalities.

"The domestic use is greatest in the towns and cities, and in the portions of the towns and cities having the greatest wealth and refinement, where water is appreciated as a luxury as well as a necessity, and this is true of the yard sprinkling and ornamental fountain use, and the private stable use. * * *

"The general introduction of public water-works on the constant supply system, with liberal pressure in the mains and house services,

*From J. T. Fanning's Hydraulic Engineering, by permission.

throughout the American towns and cities, has encouraged its liberal use in the households, so that it is believed that the *legitimate* and economical *domestic* use of water is of greater average in the American cities than in the cities of any other country, at the present time, *and its general use is steadily increasing.*"

The proportion of the above per capita per day supply naturally reaching the sewers may be summarized as follows:

(*a*)	Domestic use,	20 gallons.
(*b*)	Stables,	3 gallons.
(*c*)	Manufacturing,	5 to 15 gallons.
(*d*)	Fountains,	3 to 10 gallons.
(*g*)	Waste in winter,	10 gallons.
(*h*)	Flushing,	5 to 15 gallons.
	Total supply reaching sewers,	46 to 73 gallons.

The following table illustrates the proportional increase in water consumption during a period of ten years:

TABLE II.

Showing Consumption of Water in Twelve American Cities in 1874 and 1884.

BASED UPON THE TOTAL POPULATION.

CITIES.	Average Daily Supply per Capita in Gallons. 1874*	1884†
Boston	60	110
Brooklyn	58	63
Buffalo	60	151
Chicago	84	145
Cincinnati	45	76
Cleveland	45	88
Detroit	87	120
Jersey City	86	136
Louisville	24	64
Philadelphia	58	81
Washington	138	165
Montreal	66	88

* J. T. Fanning's Hydraulic Engineering.
† J. J. R. Croes' Statistical Tables, 1885.

The daily increasing uses to which water from city mains under a liberal pressure is put are an indication that the per capita consumption of water has not yet reached its legitimate limit.

The following table, compiled from the statistics of one hundred and seventy-six American cities, illustrates the present consumption of water:

TABLE III.

Showing Per Diem per Capita Consumption of Water in One Hundred and Seventy-Six American Cities in 1884.

BASED UPON THE TOTAL POPULATION, CENSUS OF 1880.*

CITIES. NO.	POPULATION.	Average Consumption of Water per Diem per Capita.
49	10,000 to 15,000	76
33	15,000 to 20,000	69
17	20,000 to 25,000	71
41	25,000 to 50,000	86
11	50,000 to 75,000	80
4	75,000 to 100,000	95
13	100,000 to 250,000	102
4	250,000 to 500,000	89
4	500,000 and over	92

*Compiled from J. J. R. Croes' Statistical Tables, 1885.

The above tables, II and III, though giving the average daily use, are not sufficient to predicate an assumption of sewage discharge upon, as they indicate simply averages obtained from widely varying rates of consumption. As previously stated, each day has a maximum rate of discharge, and there are also weekly and monthly maxima, varying according to the habits of people, and to the conditions of temperature, etc., and the sewers (we are considering the separate system, which has no capacity of *storage*) must be proportioned to discharge their contents at the maximum *rate* at which they are received.

Varying Rates of Water Consumption.—There are two principal maxima of water consumption, one occurring during the coldest weather, and one during the warm and dry months of late summer. It is the former which particularly influences the sewage discharge, being in most cases the maximum rate of water supply for the year, and nearly its entire volume reaching the sewer, while the uses to which water is put during the warm and dry weather maximum, diverts it largely from the sewers.

The following table indicates the monthly variations in water consumption during the year 1884, in several American cities, covering a considerable range of latitude. The computations are made from statistics appearing in official reports of the water departments of the various cities, and are reduced to the per cent. basis in terms of the average monthly consumption.

TABLE IV.

Illustrating Monthly Variation in the Consumption of Water in 1884, in which the Mean Monthly Consumption for Each City is Represented by 100.

CITIES.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Chicago,	105	107	100	102	100	98	101	102	98	95	94	96
Columbus,	138	100	107	83	90	93	106	112	100	91	87	95
New Orleans,	90	77	87	90	105	106	113	109	110	113	111	96
Cincinnati,	88	90	89	101	101	106	109	114	113	110	92	86
Wilmington,	103	79	89	83	77	125	120	114	115	106	97	90
Buffalo,	111	118	114	95	92	96	91	96	95	95	97	99
Binghamton,	116	96	97	79	90	95	98	124	107	100	104	89

From the above table we find the average maximum monthly consumption for the seven cities to be 119 6-7, or, practically, twenty per cent. in excess of the average monthly consumption.

The daily consumption has a weekly maximum independent of atmospheric conditions, and which ordinarily occurs on Monday. The widest variations in daily consumption, however, are those due to extremes of temperature.

The relative minimum, mean, and maximum daily consumption, in a few cases, is illustrated in the following table in terms of the mean daily consumption. The computations are based upon statistics contained in official reports.

TABLE V.

Illustrating Extreme Daily Variations in Consumption of Water in 1884, in which Mean Daily Consumption is Represented by 100.

CITIES.	Minimum Daily Consumption.	Mean Daily Consumption.	Maximum Daily Consumption.	
				DATE.
Chicago	82	100	120	Jan. 23
Cincinnati	60	100	152	June 24
Buffalo	68	100	140	Feb. 5
Columbus	--	100	176	Jan. 1

The average maximum daily consumption in the cities, given in Table V, is 147, or forty-seven per cent. in excess of the mean daily consumption of the year.

The average maximum daily consumption, given above, indicates only averages for a period of twenty-four hours. It will be necessary to ascertain the rate of the heaviest hour's use.

Statistics showing the hourly fluctuations in water consumption are not readily accessible. A single instance is here given. The table is computed from automatic counter readings of a direct service pumping engine in Kalamazoo, Mich.

TABLE VI.

Hourly Variations in Water Consumption, Monday, March 9, 1886.

TIME.	Gallons per Hour.	TIME.	Gallons per Hour.
1 A. M.	52,528	1 P. M.	58,520
2 "	49,964	2 "	58,128
3 "	51,464	3 "	59,360
4 "	52,472	4 "	59,640
5 "	52,864	5 "	61,040
6 "	52,332	6 "	57,232
7 "	54,880	7 "	53,928
8 "	64,708	8 "	56,560
9 "	62,160	9 "	52,640
10 "	61,600	10 "	54,880
11 "	60,844	11 "	52,752
12 M.	61,964	12 "	48,328

PERCENTAGE RELATION.

Average hourly rate,..........................100
Minimum " " 85.9
Maximum " " 115.1

If this table be examined in connection with Table IX, showing sewer gaugings taken simultaneously with the counter reading, it will be particularly interesting. A graphical representation of the two on the same sheet shows almost precisely the same relative variation in each.

The following illustrations and estimates of varying consumption are taken from J. T. Fanning's Hydraulic Engineering:

"The Brooklyn diagram shows that the average draft in the month of maximum consumption was, in 1872, fifteen per cent. in excess of the average annual draught; in 1873, seventeen per cent. in excess; in 1874, thirteen per cent. in excess.

"A Boston Highlands direct pumping diagram, lying before the writer, shows that the average draught at nine o'clock in the forenoon

was thirty-seven per cent. in excess of the average draught for three months, and that at eight o'clock A. M. on Mondays the draught was sixty per cent. in excess of the average hourly draught for three months.

"The maximum hourly draught, indicated by the two diagrams taken together, is nearly seventy-five per cent. in excess of the average throughout the year.

"In illustration, we will assume a case of a suburban town, requiring, say, an average daily consumption for the year of 1,000,000 United States gallons of water, and compute the maximum rate of draught on the basis shown by the above named diagrams, thus:

	GALLONS.
Average draught per year	1,000,000
Add 17 per cent. for maximum monthly average draught, making	1,170,000
Add to the last quantity 10 per cent. for the maximum weekly average draught, making	1,270,000
Add to the last quantity 37 per cent. for the maximum hourly average draught, making	1,640,000
Add to the last quantity 23 per cent. for the maximum hourly average draught on Mondays, making	1,870,000

"The maximum hourly draft is not infrequently one hundred per cent. in excess during several consecutive hours, independent of the occasional heavy draughts for fires."

Fanning's estimate, as given above, would require sewers capable of discharging twice the mean daily water consumption, upon the supposition that at the time of maximum consumption its entire volume reaches the sewers. And this being ordinarily in the winter months, the supposition is a reasonable one.

Sewer Gaugings.—Exact measurements of the flow of house sewage for any considerable period are not accessible, if they have ever been made, and, consequently, we can not use them as a basis in determining the fluctuations in sewage flow, or the ratio of maximum to mean discharge.

A limited number of gaugings have, however, been made with the purpose of determining the maximum rate of flow per capita in certain cases, and an account of some of them appears in a report to the National Board of Health, by G. E. Waring, Jr.

The most complete statistics recorded are those of gaugings made under the direction of Robert Moore, Esq., Civil Engineer,

Commissioner of Sewers of St. Louis. The following is an abstract from the report:

"The sewer drains an area containing 1,370 houses, occupied by a population of 8,200. The total number of water taps was 1,390. The diagrams show gaugings taken every hour from six P. M. Monday, March 15, to eleven A. M., March 16, and from 8 A. M., March 19, to 8 A. M., March 23. These gaugings are averaged to make a *typical day*, in which, beginning at midnight with a flow of 75.32 cubic feet per minute, the flow was reduced to 70.26 cubic feet per minute at 6 A. M., 130.26 cubic feet per minute at 11 A. M., 123.86 cubic feet per minute at 3 P. M., and steadily declined from this time until midnight, when the flow was 75.15 cubic feet per minute. The sewer is seven feet, three inches in diameter. It was obstructed by a dam, into which was built a twelve inch vitrified sewer pipe, which was continued for a length of twenty feet. The gaugings were taken simultaneously at three different points, the average of these being the assumed depth through the twenty feet of twelve inch pipe."

The following is a condensed tabular statement of the results obtained, as stated in the report:

TABLE VII.

Sewer Gaugings Made at St. Louis.

	DATA.				DEDUCTIONS.				
DATE OF OBSERVATION.	Greatest Discharge in Cubic Feet per Minute.	Greatest Depth in Feet.	Least Discharge in Cubic Feet per Minute.	Least Depth in Feet.	Average Discharge in Cubic Feet per Minute.	Average Depth in Feet.	Velocity in Feet per Second. Greatest.	Least.	Average.
March 15–16..	154.25	.5833	74.67	.3751	42.39	.4356	5.41	4.54	4.69
" 19..	144.09	.5341	77.64	.3985	114.30	.4689	5.65	4.43	5.27
" 20..	132.34	.5144	67.06	.3751	102.18	.4519	5.41	4.16	4.94
" 21..	133.79	.5177	68.58	.3568	96.49	.4298	5.86	4.27	4.93
" 22..	123.57	.4961	69.54	.3802	101.78	.4452	5.54	4.23	5.02
" 23..	118.79	.4701	73.95	.3725	79.74	.3940	5.46	4.47	4.61
Typical Day, or Average of March 20, 21, and 22					100.22	.4420	5.86	4.16	4.99

Number of houses connected with the sewer	1,370
Population	8,200
Number of water taps	1,391
Cubic feet of sewage discharged per capita in twenty-four hours	17.60

Upon the foregoing statistics, the following comment is made in the report:

"A computation of the amount of flow as compared with the population makes it evident that the sewer must have received a very large amount of ground water, for the total flow (over 1,000,000 gallons per day) amounted to more than 130 gallons for each member of the population, which, in a district having only about one water tap to each house, would be an impossible amount. It is usual to estimate a maximum daily use for domestic purposes of about thirty-three gallons per head of population. Deciding the total flow by this amount, we might assume that the twelve inch pipe in this instance, carrying, at its maximum, less than seven inches in depth of water, was doing the amount of work that would be required for carrying the sewage only of a population of 30,000, supposing the sewers to be absolutely tight, so that only house-hold wastes should enter them. This last example is, from its extent, and from the minuteness with which its details are worked out, the most important of the series. It seems to me to furnish a conclusive argument—an argument fully sustained by all of the other gaugings—in favor of the safety of depending upon very small conduits for the removal of the dry weather flow of sewage of cities and towns. It shows conclusively that the commission of the National Board of Health, which recommended the system carried out in Memphis—lateral sewers six inches in diameter, main outlet twenty inches in diameter—for a prospective population of 60,000, provided a wide margin for contingencies."

Some of the conclusions drawn above are not justified by recent experience, and do not seem to be supported by the statistics of water consumption or by other gaugings on which they are predicated.

The statistics of water consumption in St. Louis show an average per diem consumption for each tap of 1,177 gallons for the entire city. Assuming the territory tributary to the sewer in which these gaugings were taken to represent an average consumption for the city, the volume of sewage as found, 17.60 cubic feet, or 131.6 gallons per diem per capita, represents a trifle less than two-thirds the total average water consumption for the territory tributary to the sewer. The diversion of more than one-third of the total water supply from the sewers, at the season at which these gaugings were made, would, in many cases, cause a public nuisance.

If the assumption of thirty-three gallons per diem per capita be properly founded on the observations made, it must be from some known local condition and not solely on the statistics as

given, which are not widely at variance with similar observations made at points where it is known there can be no infiltration of sub-soil water.

The results of other investigations published in the report are not reduced to gallons per diem per capita, but, for the purpose of more readily comparing them with the gaugings made at St. Louis and elsewhere, the following table has been compiled from computations based upon the dimensions and measurements given in the report. The results were obtained by graphical methods, but are intended to be closely approximate.

The gaugings were ordinarily taken by inserting a pipe of smaller diameter in the sewers, through which the flow was directed and in which its depth was measured. The precise manner in which these smaller pipes were placed is not stated in every case, but, as the object of the gaugings was to "determine the actual pipe capacity required" in the several cases, it seems proper to assume that they were so placed as to secure results identical with those if the entire sewer had been of an equal diameter. This is assumed in the computations made.

The gaugings of the College street sewer at Burlington, Vt., were taken at intervals of fifteen minutes from 7:30 A. M. to 10:30 A. M. The district which it drains contains eighty-five houses, of which fifty-four are connected with the sewer. The population tributary to the sewer embraces 325. There were two equal maxima in the flow, one occurring at 7:45 A. M., and the other at 9 A. M. The mean rate of discharge in this case does not represent the mean daily rate, but the mean rate during the time the gaugings were taken—7:45 A. M. to 9 A. M.

TABLE VIII.

Comparison of Sewer Gaugings.

SEWER.	Length in Feet.	Diameter in Inches.	Fall per 100.	DEPTH OF FLOW IN INCHES.			POPULATION.		Rate of Discharge per Diem per Capita.		
				Minimum.	Mean.	Maximum.	Total.	Tributary to Sewer.	Minimum.	Mean.	Maximum.
Report of National Board of Health. 1880											
Compton Avenue Sewer, St. Louis, Mo. Monday and Tuesday, March 15 and 16	......	12	......	4.50	5.22	7.00	8,200	......	98	121	202
Same, Saturday, March 20	......	12	......	4.50	5.42	6.17	8,200	......	90	134	173
Same, Typical Day	......	12	......	4.44	5.30	6.25	8,200	......	94	131	178
College St. Sewer, Burlington, Vt.	2,790	6	1.12	.80	1.04	1.20	......	325	65	115	140
Huron St. Sewer, Milwaukee, Wis.	......	10	.25	......	......	4.50	......	3,177	......	......	120
Same	......	10	.25	......	......	4.50	4,035	......	......	......	94
Other Sources. 1881											
Main Outlet, Memphis, Tenn.	105,600	20	.166	8.50	......	14.50	35,000	......	35	......	80
State Asylum for the Insane, Kalamazoo, Mich.	......	6	.50	......	......	......	1,000	......	......	......	176

The following is an account of the gaugings taken in the Memphis main sewer by C. H. Latrobe, C. E., and is quoted from his report to the Mayor and City Council of Baltimore:

"By gaugings taken at the head of the twenty-inch main I found the hourly flow of sewage to be remarkably uniform. Thus, from six A. M. till one A. M. the following morning, a period of twenty hours, the flow oscillated in centre-depth from twelve and one-half to fourteen and one-half inches, the minimum area of flow being 206.5 square inches; the maximum, 245.73 square inches. From one A. M. till five A. M., a period of four hours, the centre depth of flow varied from eight and one-half inches to eleven and one-half inches, minimum area being 107.6 square inches; maximum area, 186.9 square inches. Taking the twenty-four hours, the minimum flow is 43.7 per cent. of the maximum; taking the twenty-four hours of greatest flow, the minimum is 84 per cent. of the maximum and eight-ninths of the daily flow of sewage passed in twenty hours, one-ninth in four hours. This marked uniformity of flow during twenty hours of the day and its oscillating character within such limits, must be somewhat influenced by the action of the flush-tanks, which probably discharged in small groups. * * * The accompanying system of tile drains has also thoroughly drained (as far as I know) the very tenacious sub-soil of the city. * * * *

"The errors or omissions in the Memphis system are:

"First. Insufficient size in the mains to accommodate the excessive use or waste of water during severe winters, when people allow spigots to run all the time, to prevent freezing. During the winter just ended Major Humphries estimates that *one hundred gallons* per capita per day were often used, which caused the mains to run full bore and occasioned a backing up of the sewage in the lower parts of the city. This fault, of course, was not incident at all to the system, but was an oversight in proportioning the mains, and would not be felt during an ordinary winter."

Since in the case of Memphis special provision was made for the removal of the sub-soil water by separate channels, it is improbable that the flow of the sewers proper was augmented by it.

It must be borne in mind that these gaugings were made before the completion of the system at Memphis, and represent the discharge from but a limited portion of the territory upon which the per capita discharge is based, there being at that time but twenty miles of the system complete. It has since been extended to about forty miles. On the other hand, the introduction of the system into the houses was so general and prompt, that it is probable the territory sewered reached more nearly its maximum rate of discharge within the short time intervening be-

tween its completion and the time at which the gaugings were taken than would ordinarily be the case.

The maximum rate of sewage discharge, then, as shown in Table VIII (eighty gallons per diem per capita), should properly be based on a much smaller population than 35,000. (The total population of the city, as given in the census of 1880, is but 33,590.) No means of determining the population occupying the territory actually tributary to this twenty miles of sewers are at hand, but it has been estimated at 20,000. Upon this basis the maximum rate of discharge of eighty gallons, as shown in the table, becomes 140 gallons.

The population actually tributary to the Compton Avenue sewer at St Louis is not stated. If, in the case of the gaugings made in this sewer on Saturday, March 20, it be assumed that at the time of minimum flow, the entire volume discharged was sub-soil water (which is certainly not a proper assumption, since at no time during the twenty-four hours is the discharge of house sewage in a system of any extent wholly arrested), and its total amount at this assumed rate for the twenty-four hours be deducted from the discharge, as shown by the gaugings, the volume of discharge remaining aggregates 43.4 gallons per diem per capita.

Again, if we assume the hourly variations of flow, as determined by the gaugings taken at Memphis, to be a proper range for St. Louis, or, in other words, assume that the ratio of minimum and maximum discharge of *house sewage* only, in the two cities is the same, we can determine the amount of sub-soil water and eliminate it. A computation made on this assumption gives us in St. Louis, for the discharge of house sewage only, when based on the total population occupying the territory, minimum, 65 gallons; mean, 102 gallons; maximum, 149 gallons per diem per capita.

The gaugings made at the Compton Avenue sewer, St. Louis, cover the entire twenty-four hours. They are illustrated graphically in the diagrams on opposite page, taken from the report.

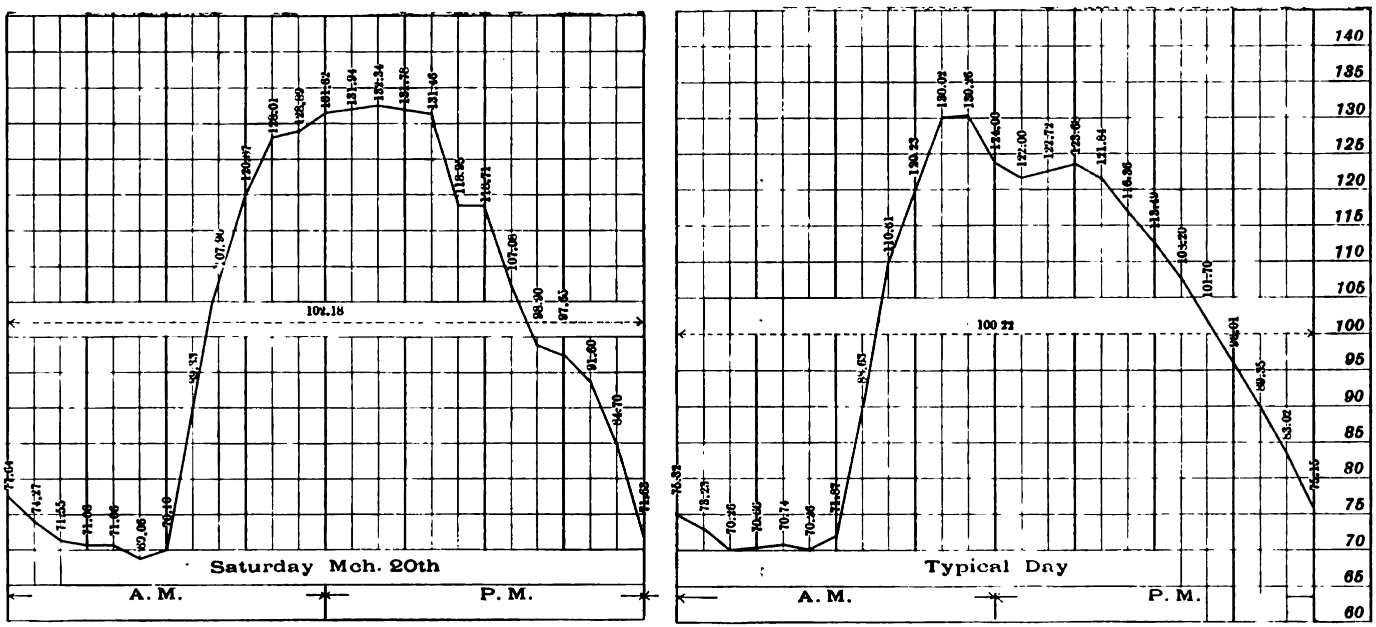


Diagram of Sewer Gaugings Made in the Compton Avenue Sewer, St. Louis.

Gaugings were made of the flow of the Water Street Main in Kalamazoo, Mich., on March 9, 1885, as follows:

TABLE IX.

Discharge of Water Street Main Sewer, Kalamazoo, Mich., Monday, March 9, 1885.

TIME.	Discharge in Gallons per Minute.			
1 A. M.	233			
2 "	227			
3 "	224	Minimum	Average discharge per minute	254 Gallons.
4 "	230			
5 "	234			
6 "	242		Maximum discharge per minute	287 "
7 "	244			
8 "	265			
9 "	255		Minimum discharge per minute	224 "
10 "	265			
11 "	258			
12 M.	258			
1 P. M.	255			
2 "	265			
3 "	273		Percentage Relation of Maximum and Minimum Discharge to Mean Discharge.	
4 "	287	Maximum		
5 "	275			
6 "	276			
7 "	265			
8 "	257		Minimum discharge	88
9 "	255			
10 "	255		Mean discharge	100
11 "	253			
12 "	250		Maximum discharge	113

These gaugings at Kalamazoo were made by weir measurement in the manner illustrated in Fig. 1.

The weir is made of galvanized sheet iron of the ordinary weight, rolled up in the form of a funnel, and riveted or lapped and soldered, its smaller end being slightly smaller in diameter than the sewer in which it is to be inserted. The larger end is cut off at right angles to the side which is to lie in the bottom of the man-hole, and on this is fastened an end, having cut in it the notch forming the weir, as shown at (*b*). The weir should stand sufficiently above the man-hole to counteract the effect of velocity of entry, and to give a free *run* to the sewage. The depth of

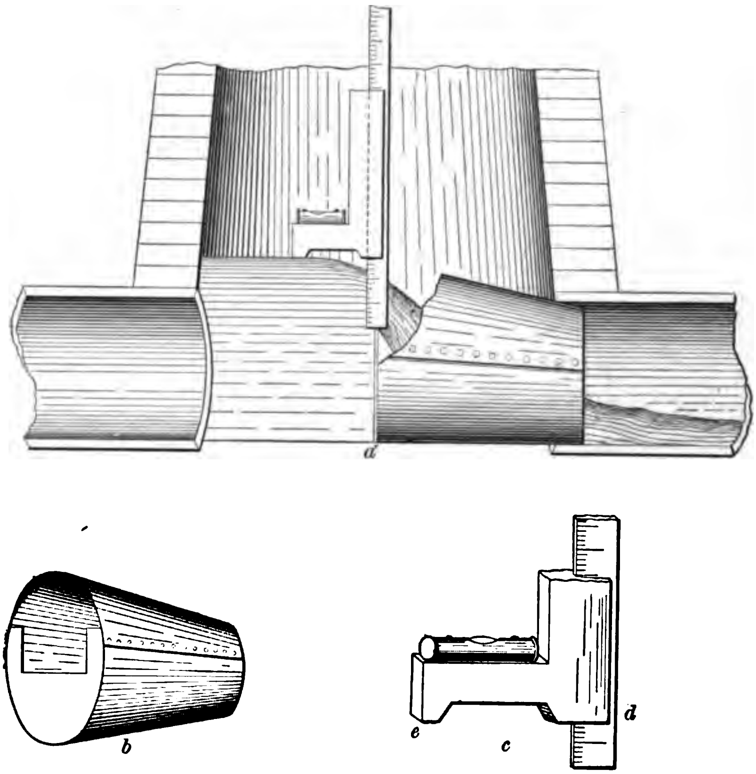


FIG. 1.

discharge over the weir is measured by a thin, graduated strip, on which travels a block having a level attached for bringing the scale into a vertical position, and the point of contact with the surface of the water level with the index or point of reading at *d*. Still more accurate results might be had by taking the measurement from some fixed point above the weir, but in ordinary cases the method detailed above will be sufficiently accurate.

The weir is easily transferred from one point to another, and is quickly set, requiring but a piece of cloth wrapped around the lower part, when it can be crowded into the lower branch of a man-hole, where its flexibility insures a perfect fit, and the pressure of water from above keeps it to its place. It is also very convenient in use, the observation being taken from above,

where the peculiar light makes the least ripple of water against the point *e*, and the position of the level bubble plainly distinguishable.

The method of observing the depth of flow in the sewer proper and computing from these data the discharge by formula or tables, though frequently used, is liable to error. The slightest obstruction below the point of observation increases the observed depth, and, consequently, gives results too high, since the diminished velocity at the point of observation is not noted. A slight increase of flatness in the grade at the point at which the observations are taken, below the grade at which the sewer may have been laid originally, has the same effect, as also the depression of a single joint or section of pipe. Opposite conditions, by increasing the velocity or by raising the measuring scale, will give results too low.

In the case of pipes of smaller diameter inserted in larger sewers, there are also difficulties in the way of securing correct results. The following gaugings, made at Milwaukee, will illustrate this point. They were made under the direction of G. E. Waring, by A. H. Scott, C. E., for the National Board of Health, and a statement of them appears in the report of 1880. They were made in this way for a particular object:

"Formulæ in use among engineers would lead us to substantially the same result with actual gaugings, but their educational effect would be less marked, because calculations based upon scientific formulæ are less readily comprehended by the average municipal ruler. * * *

"The grade of the sewer at the point where the gaugings were taken is about 1 in 400. The greatest flow in the main sewer on 'washing day'—the greatest flow of the week—attained a depth of six inches, the diameter of the sewer being forty-two inches. The channel being reduced to a diameter of ten inches, the greatest depth of flow was 4.5 inches. Reduced to a diameter of eight inches, the depth remained the same—4.5 inches. Reduced to a diameter of six inches, it reached a depth of 5.5 inches. The influence on the velocity of the stream by increasing its hydraulic mean depth is illustrated by the following figures:

"Forty-two inch sewer, six inches deep; cross section of stream	121.3 square inches.
Ten inch sewer, 4.5 inches deep; cross section of stream	33.1 square inches.
Eight inch sewer, 4.5 inches deep; cross section of stream	27.7 square inches.
Six inch sewer, 5.5 inches deep; cross section of stream	27.14 square inches."

These figures illustrate very forcibly the superior cleansing effect of sewers discharging half full or more. They also illustrate the difficulty in securing uniform results previously cited, as shown by the following computations. The volume discharged in each case is stated as the same. The computed discharge is, approximately, as follows, leaving out of consideration the forty-two inch sewer:

Diameter.	Depth.	Discharge in Cubic Ft.
10 inches.	4.5 inches.	30.45
8 inches.	4.5 inches.	23.06
6 inches.	5.5 inches.	17.48

The inaccuracies of this manner of measuring flow become still more apparent as the depth of flow becomes less in proportion to the diameter of sewer.

From the statistics of water consumption in the preceding pages, we may conclude that the discharge of *house sewage*, at its maximum hourly flow during the year, is approximately twice the mean discharge.

The records of sewage discharge show a variation during single days covered by the observations of thirty, forty, and in the case of the Compton Avenue sewer at St. Louis, on March 15 and 16, of nearly seventy per cent. above the mean daily rate. Observations covering a longer period and varying conditions of temperature would, undoubtedly, indicate a still greater maximum rate of discharge.

CHAPTER VI.

LAWS OF FLOW IN SEWERS.

A circular sewer reaches its greatest capacity of discharge when its depth of flow is about .933 of its diameter, being at this point nearly eleven per cent. in excess of that attained when running full. When the depth of flow is half the diameter, the velocity is equal to that when the sewer is running full and not under pressure.

Circular sewers should be so proportioned as to size, throughout the system, that the depth of the ordinary daily flow will be sufficient to induce a fair velocity, and prevent deposits.

The transporting power of circular sewers of small diameter is dependent on the depth of flow in great measure, as well as on grade and velocity. A stream having a depth of flow sufficient to immerse solid matter held in suspension, to a certain extent lifts it and carries it forward. The entire surface is also exposed to the action of the current. A stream having an equal velocity but a less depth in proportion to the diameter of the solid matters to be transported, evidently has less transporting power. As an illustration, a stream can be easily forded when its depth is below a man's waist, while the same stream in deeper water, even though the velocity be less, will carry a person down stream.

Effect of Increasing Size.—An amount of sewage which can be properly transported by a six inch circular sewer, cannot be as efficiently transported by one of larger diameter, as the following comparison will show: If we assume the contents of a sewer of six inches in diameter, laid at a grade of .5 per hundred, and discharging half full, to be diverted to sewers of eight, ten, twelve and fifteen inches in diameter respectively, and laid at the same grade, the following depths and velocities will be attained, theoretically:

TABLE X.

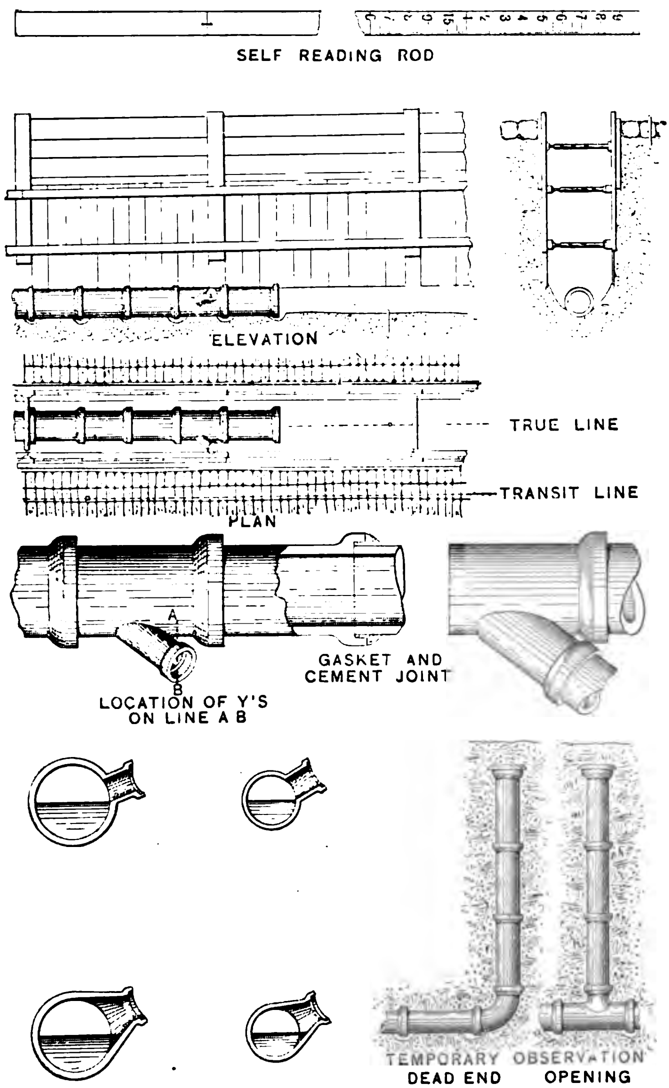
Illustrating Effect of Increased Section, the Volume of Discharge Remaining the Same.

SEWER.	Depth of Flow.	Velocity in Feet per Minute.	Discharge in Cubic Feet per Minute.
6 inch sewer.	3.00 inches.	147	14.40
8 " "	1.92 "	129	14.40
10 " "	1.36 "	112	14.40
12 " "	1.03 "	100	14.40
15 " "	.75 "	83	14.40

From the above comparison, we see that both the velocity and depth, each of which is a factor in the transporting power of the sewer, and, consequently, a measure of its effectiveness, decrease as the size of pipe is increased. Like results have been shown practically in many cases, by the substitution of lateral sewers of smaller diameter in place of those which have not had depth of flow sufficient to be self-cleansing.

On the other hand, the most perfect working of the house sewers demands that they have a free out-fall into the lateral, as shown by the section in Plate I. A majority of the stoppages in house sewers occur at their entrance into the laterals and mains, and if the flow in the laterals and mains be deep enough to seal the outlet of the house sewers, the discharge of floating paper, etc., is arrested, and the difficulty at this point very much aggravated. Good ventilation also demands a free passage of air currents through every part of the mains, laterals, and house drains. The connection of the house sewer with the street sewer is ordinarily and properly made with the common Y branch, elevated, as shown by section in Plate I. It is not made right and left hand, and when laid the sewer cannot be charged more than half bore without setting up into the house drain. The ordinary daily flow, then, for the reasons stated, should be accommodated below the horizontal diameter. An occasional extreme discharge of *short duration*, reaching the full capacity of the sewer, will be beneficial rather than otherwise.

PLATE I.


SELF READING ROD
ELEVATION
TRUE LINE
TRANSIT LINE
PLAN
A
B
LOCATION OF Y'S
ON LINE A B
GASKET AND
CEMENT JOINT
TEMPORARY
DEAD END
OBSERVATION
OPENING

Effect of Hydraulic Mean Radius.—The comparative velocity and discharge of circular sewers when running at different depths, is well illustrated by the following table:

TABLE XI.

Showing the Comparative Discharge and Velocity in Circular Sewers of a Given Diameter and Grade for Various Depths of Flow.

[The depth of flow is expressed in terms of the diameter. The velocity and discharge are expressed in terms of the velocity and discharge when the sewer is running full, or when depth=1.]

Depth of Flow.	Velocity.	Discharge.
.067	.414	.0277
.100	.498	.0498
.1465	.602	.0883
.200	.6942	.1388
.250	.7698	.1914
.300	.8210	.2463
.400	.9264	.3702
.500	1.0000	.5000
.600	1.0534	.6302
.700	1.0932	.7642
.750	1.0984	.8238
.800	1.1028	.8822
.8535	1.1010	.9397
.900	1.0918	.9826
.933	1.0794	1.0071
1.000	1.0000	1.0000

If from the above table we construct the curves of velocity and discharge by laying off the depth of flow and the velocity and discharge as co-ordinates, the effect of the respective depths of flow upon velocity and discharge will be more apparent to the eye.

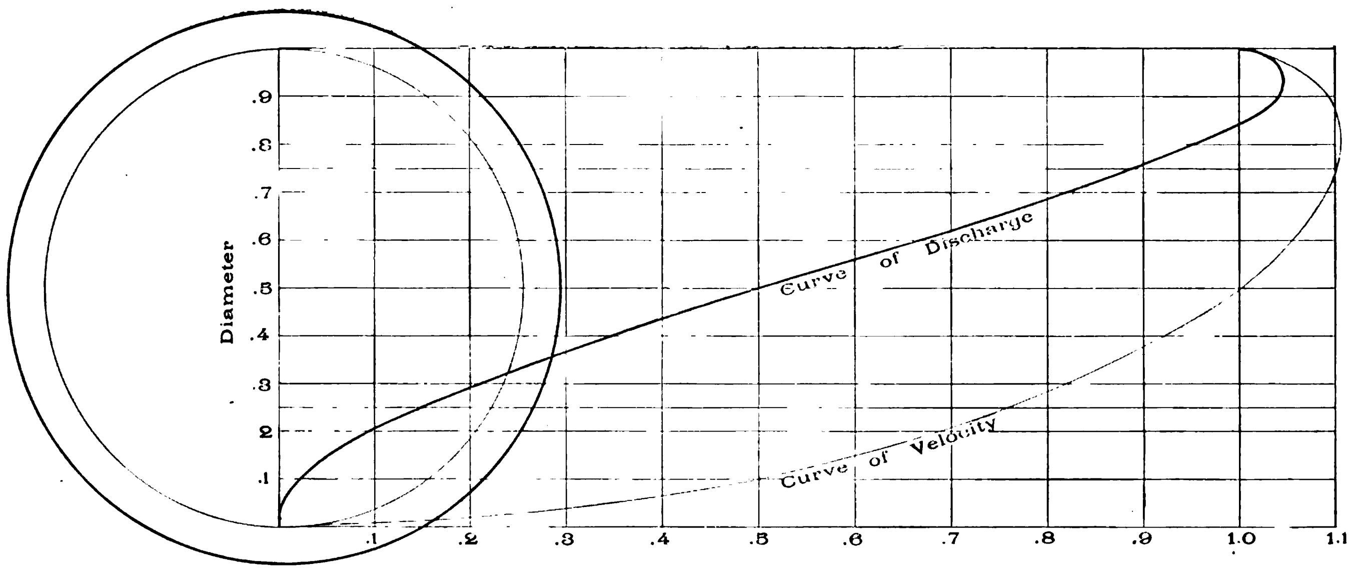


Diagram Showing Comparative Velocity and Discharge in Circular Sewers of a Given Diameter and Grade, for Various Depths of Flow.

Computation of Discharge and Velocity for any Diameter and any Depth of Flow.—The diagram opposite affords a very convenient and closely approximate method of computing the discharge of any circular sewer discharging at any depth.

Nearly all hydraulic tables bearing on this subject are computed to give the discharge of sewers running full bore. A few give the discharge when flowing one-quarter, one-third, one-half, two-thirds, or three-quarters full. This is about as wide a range as can be covered without making the tables too bulky for convenience.

The discharge of a circular sewer of any size and grade, and flowing at any depth, can be determined from the diagram, as follows:

Divide the depth of flow by the diameter, and from the fractional depth on the vertical diameter thus indicated draw (by the eye) a horizontal line, intersecting the curve of discharge, and from its point of intersection a vertical to the base. The percentage thus determined on the base, will be the relation of the discharge required to the discharge of the sewer when running full, which can be taken from the table, thus:

Given,

Diameter of sewer=12 inches.
Grade =1 in 200.
Depth of flow =5 inches.

Required, the discharge.

Solution:

$$\frac{5}{12}=.416.$$

Tracing a horizontal line from .416 on the vertical diameter to its intersection with curve of discharge, we read from the scale below .36. The discharge is thirty-six per cent. of that if the sewer were running full. From Baldwin Latham's Tables we see discharge when running full=167.2 cubic feet per minute. $167.2 \times .36 = 60.192$ cubic feet per minute, which is the required discharge.

The velocity of any circular sewer, flowing at any depth, can be ascertained from the diagram in the same way. The di-

agram has been carefully reduced to scale of one-half inch horizontal and one-fourth inch vertical, to facilitate calculations of this kind, and the fractional divisions can be read by applying an ordinary engineer's scale.

It is probable that neither the velocity or discharge of sewers, whose depth of flow is but a small percentage of their diameters, attain in practice the value theory ascribes to them, since the solid matter held in suspension in all sewage becomes partially stranded, or is not lifted clear of the invert of the sewer, and the co-efficients of resistance appearing in the formula, being applicable to a liquid only, give results too great.

Velocity Required to Prevent Deposit.—The velocity necessary to prevent deposit in sewers is variously estimated at from one to three feet per second by different authorities. Baldwin Latham states that he has found that, in order to prevent deposits in small, circular sewers, such as those of six-inch and nine-inch diameter, a velocity of not less than three feet per second should be produced. Sewers from twelve to twenty-four inches in diameter should have a velocity not less than 2½ feet per second, and sewers of larger diameter should in no case have a less velocity than two feet per second. The minimum inclination securing these velocities in the several cases, assuming the sewers to run half full or full, is:

6-inch pipe	1 in 142=.704 per 100
9-inch pipe	1 in 203=.494 per 100
12-inch pipe	1 in 385=.260 per 100
24-inch pipe	1 in 775=.129 per 100

The minimum velocity recommended by several authorities is as follows:

Baldwin Latham	2 to 3 feet per second.
Beardmore	2½ to 3 feet per second.
J. Phillips	2½ to 3 feet per second.
Rankin	1 to 4 feet per second.
J. W. Adams	2½ to 3 feet per second.
Philbrick	2½ to 3 feet per second.
Gerhard	2 to 3 feet per second.

While in extreme cases sewers may be laid at an inclination inducing only a velocity of two feet per second, with reasonable expectation of their serving a good purpose, it cannot be denied that they are less satisfactory in their workings, and require more care in their maintenance, especially in the upper levels of the system, where the volume of sewage is less constant.

Effect of Decreasing Quantity of Sewage.—It must be borne in mind that the flow decreases in volume in arithmetical ratio as we ascend the sewer, becoming zero at the summit. In illustration: If we assume a six-inch sewer 4,000 feet long, with a grade of .48 per 100, to have a tributary population for each 100 feet of its length of fifty persons, and each person to contribute fifty gallons per day of sewage, to be discharged in sixteen hours, with the sewer running half full, the computed maximum velocity at its lowest level, becomes, approximately, 144 feet per minute. The volume of sewage, however, at distances of 250, 500, 1,000, 2,000 and 3,000 feet from its summit, is but $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ of that at the point where it is running half full, and, by computation, supposing the sewer laid at a uniform grade, the theoretical velocities at these points become, approximately, as follows:

Distance ----	250 ft.	Velocity ----	73.4	ft.	per min.
" ----	500 "	" ----	89.	"	"
" ----	1000 "	" ----	105.11	"	"
" ----	2000 "	" ----	[illegible].42	"	"
" ----	3000 "	" ----	135.88	"	"
" ----	4000 "	" ----	144.	"	"

Or, assuming the inclination to be increased as we approach the summit, so that the velocity shall be maintained at the uniform rate of 144 feet per minute, the inclination at the several points, theoretically, becomes about as follows:

DISTANCE.	INCLINATION.		
250 feet ----------------------	1 in 58.8 =	1.700	per 100
500 " ----------------------	1 " 85. =	1.176	" 100
1000 " ----------------------	1 " 113.3 =	.870	" 100
2000 " ----------------------	1 " 158. =	.632	" 100
3000 " ----------------------	1 " 185. =	.540	" 100
4000 " ----------------------	1 " 208. =	.480	" 100

These figures very plainly illustrate what is so often observed in practice, and explain the frequency of stoppages in the higher levels of a system of sewers. They also illustrate the great benefit to be derived from the use of automatic flushing tanks at dead ends, by which the sewer is intermittently filled to a fair working capacity, and its stranded contents swept on to the mains before they have accumulated to a degree interfering with the working of the sewer. Flushing tanks at dead ends so surely counteract the defects above stated, that lateral sewers, to which they are applied, may be designed with uniform inclination throughout.

The grade of streets frequently prevents the inclination of sewers being increased to the proper degree toward the summits. and in this case flush tanks are indispensable.

Minimum Velocity.—Six-inch lateral sewers laid at a grade of .4 per 100 (1 in 250) are fairly satisfactory in their workings, when supplied with automatic flushing tanks. The theoretical velocity in this case is 131 feet per minute when running half full. There is a marked difference observed, however, when the inclination is increased to .5 per 100, and the velocity to 147 feet per minute, especially during that portion of the day when the sewer is discharging below its average rate. Sewers of this diameter and grade are uniformly found in good condition when properly constructed and maintained; and, unless there is good reason to the contrary, the inclination should be sufficient to secure this velocity. The velocity in sewers of larger diameter may be somewhat less, as being ordinarily mains, their flow is more constant, and, having a greater actual depth of flow, suspended matters are wholly immersed and lose weight in a greater degree, and, consequently, are transported at a lower velocity.

Unless special means are taken to prevent deposit, the following may be taken as minimum velocities in circular pipe sewers:

TABLE XII.

Minimum Velocities and Grades in Circular Sewers.

Diameter of Sewer.	Velocity in Feet per Minute.	Theoretical Inclination when Depth of Flow Equals One-Half the Diameter.	
		FRACTIONAL.	PER 100.
6	147	1 in 200	.5000
8	144	1 " 280	.3571
9	142.5	1 " 320	.3125
10	141	1 " 360	.2777
12	138	1 " 450	.2222
15	134	1 " 600	.1666
18	129	1 " 760	.1315
20	126	1 " 890	.1123
24	120	1 " 1,160	.0832

Main outlet sewers lying beyond the point where houses are connected with the sewers, and which may safely work under light pressure at times, may have a lower inclination.

Where it is impossible to secure the grades above given, special precaution should be taken to keep the sewers free. Low grades have been adopted in many cases as a choice of evils, and by special precautions have been made to serve a good purpose. The following are examples:

"At Wave Crest, Rockaway, L. I., a four-inch sewer has been laid across a salt marsh for a distance of 2,800 feet. This small pipe is nearly level, the total fall being only three inches; yet, during the nine years in which it has been in use no stoppages have occurred, and no trouble of any sort has been met with. There are twenty-three houses on this line of pipe, most of which have their water-closets and one or two bath-tubs. A flush-tank at the end of the line of pipe is supplied by means of a wind-mill."—*Andrews in N. Y. State Board of Health.*

Undoubtedly, from the facts above given, the lower levels of this sewer work under a head, at least during portions of the

time, and the velocity is measured, not by the fall divided by the length ($\frac{.25}{2800}$), but by a certain head greater than .25 divided by the length.

A main sewer in Kalamazoo, Mich., has a fall of but 1 in 1,200 for a distance of 7,400 feet. The lower 5,000 feet of this sewer is twelve inches in diameter, and the upper 2,400 feet is ten inches in diameter. The discharge is ordinarily at a rate of about 250 gallons per minute at its maximum, as taken by weir measurement. Theoretically, this should fill the twelve-inch pipe about half of its vertical diameter, and the ten-inch pipe about two-thirds of its vertical diameter. Actually the sewer is often full nearly to its crown.

This sewer has been in use four years, and there has been no serious difficulty. There is a tendency toward deposits, however, but as the sewer has few connections on this portion of its length, any tendency of this kind resulting in decreased sectional area sets the sewage back until the head thus gained induces a velocity which effectively removes all deposits

Neither of these cases, then, can be considered as warranting us in adopting these grades for a sewer which is to be tapped throughout its length by house branches, and whose crown should have air space for ventilation.

If we assume a minimum velocity of 180 feet per minute for house drains, the theoretical inclination under the above supposition (running half full) would be one in ninety-two for a four-inch sewer. A sewer of this diameter and grade, running half full, would discharge 7.85 cubic feet per minute. If we assume it to be used by a family of six persons, using 75 gallons per head per diem, the total per diem discharge becomes 450 gallons. Assuming the maximum rate of discharge at 150 per cent. of the mean rate, the maximum discharge becomes .0624 cubic feet per minute, or only eight-tenths of one per cent. of the volume necessary to secure the assumed velocity of 180 feet per minute at the grade of 1 in 92. The assumed velocity would only be reached in the case of a four-inch pipe, laid at a grade of 1 in 92, as assumed above, by increasing the number of users from 6 to 750. The actual maximum velocity obtained in the sewer when used by six persons, as above, is somewhat less than .3 its velocity when running half full, or 54 feet per minute.

It is evident that in ordinary cases a grade of 1 in 92 in house drains will not be sufficient to prevent the stranding of solid matters. Four-inch house sewers should have a grade of 1 in 60, at least, and ordinarily of 1 in 48, and unless this can be obtained special precautions should be taken against stoppage. It is evident from an inspection of Table X that a sewer of six inches in diameter laid at the same grade, though having a greater velocity when working up to its capacity, would in this case, where the volume of flow is limited, give results inferior to a 4-inch sewer.

Graphical Solution.—A graphical indication of the relations of the extent of the system, tributary population, discharge, inclination and velocity, though giving but approximate results, is much more convenient in use. It makes the relation of the several factors more apparent to the eye, and assists in giving the system a proper balance. It is sufficiently accurate for all ordinary computations.

A diagram showing at a glance the relation of these factors, and by which may be solved graphically and in their proper order, the problems presented, will be found opposite page 81. It is based upon the standard tables of Baldwin Latham, and upon original computations and investigations.

The diagram is based upon the supposition that the depth of flow equals one-half the diameter at the time of average maximum daily flow, which is assumed at 150 per cent. of the mean daily flow for the twenty-four hours, or, a maximum rate of discharge equal to the discharge of the sewage of the twenty-four hours in sixteen hours.

This relative maximum rate, though somewhat below that assumed by some authorities, will seldom be exceeded in American cities, where water is freely used, and where the waste, which is less intermittingly discharged than water legitimately used, is a large proportion of the sewage.

The following table exhibits approximately the maximum rate in several cases, expressed in terms of the time required for the discharge of twenty-four hours' sewage:

TABLE XIII.

Showing Maximum Rate of Sewage Flow.

Gaugings Taken at	Time of Discharge of Twenty-Four Hours Sewage at Maximum Rate.
St. Louis, Mo.,	14.3 hours.
" "	18.6 "
" "	17.6 "
" "	16.4* "
Burlington, Vt.,	19.7 "
Memphis,	17.25 "
Kalamazoo,	21.2 "

* Eliminating sub-soil water upon the supposition made on page 60.

Upon the assumption previously made, that the maximum rate of discharge for the year may reach twice the mean daily discharge, the maximum rate for the year will be one-third greater than that given in the table. The following is a comparison of the conditions of minimum, mean, and maximum daily discharge, and of the maximum discharge for the years represented by 60, 100, 150 and 200 per cent. respectively, as appears consistent from the investigations made:

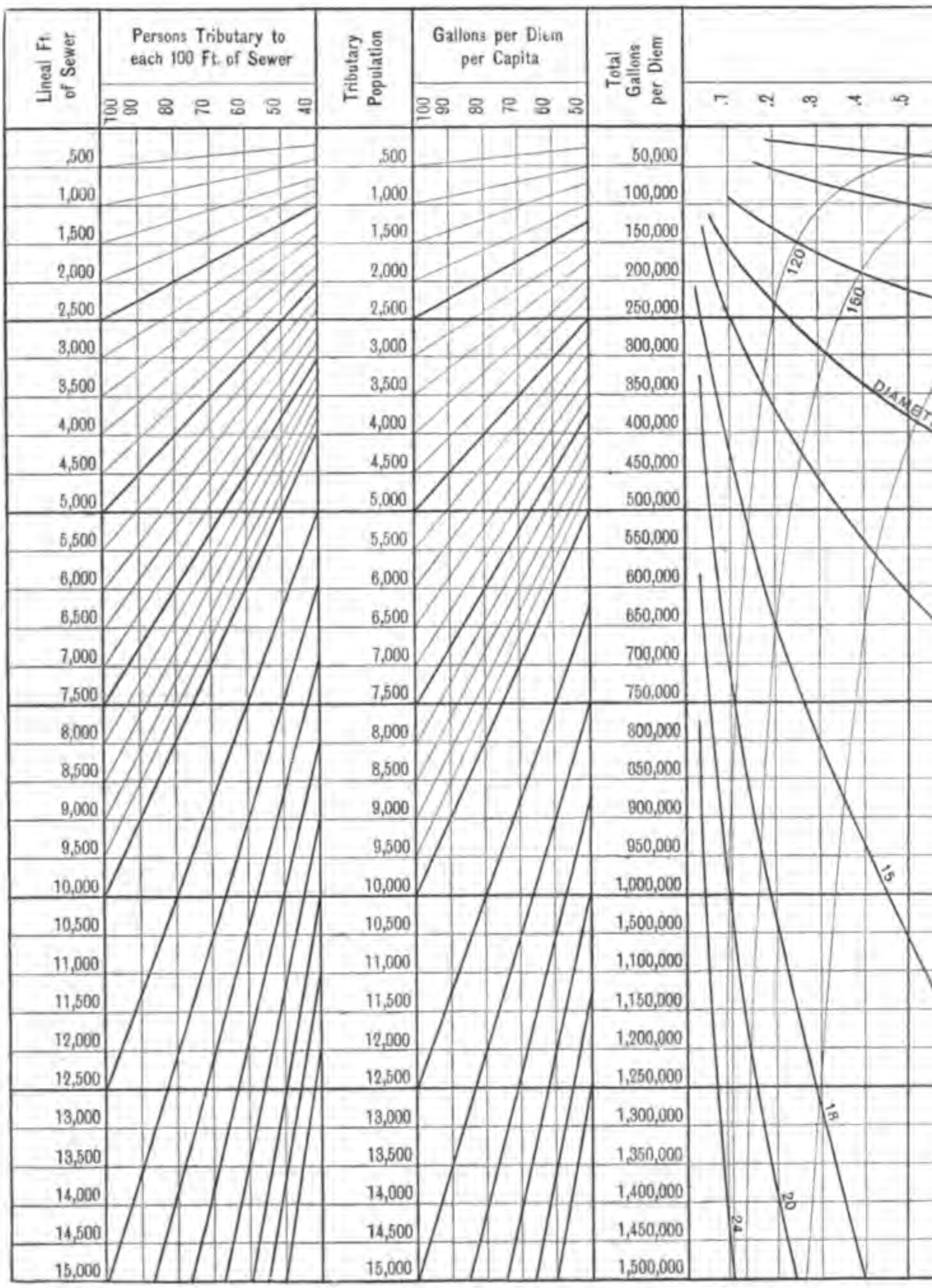
Discharge.	Per cent.	Depth of Flow in Terms of Diameter.	Velocity in Terms of V. when Half Full.
Minimum Daily,	60	.29	.82
Mean "	100	.39	.92
Maximum "	150	.50	1.00
Maximum Yearly,	200	.60	1.05

The total theoretical capacity becomes 300 per cent., which is equal to a margin of fifty per cent. above the greatest anticipated discharge. This would not be realized in practice, as the

GRAPHICAL SEWE

BASED ON BALDWIN LATHAM'S TABI

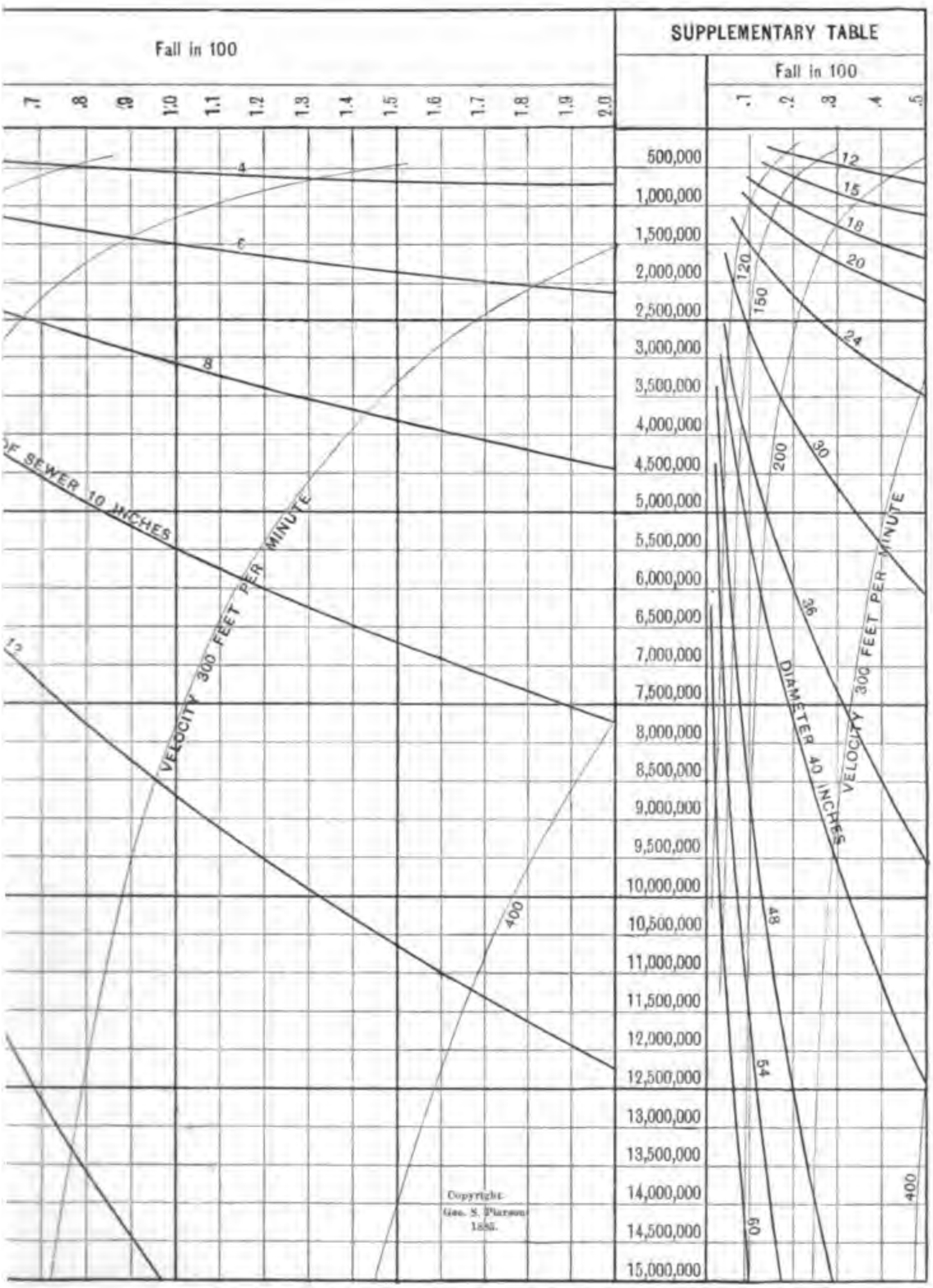
COMPILED BY GE



R CALCULATIONS.

S AND ON ORIGINAL CALCULATIONS.

S. PIERSON, C. E.



effect of numerous Y branches near the crown of the sewer and the flow from tributary house drains, prevent the stream from reaching its theoretical velocity.

While the margin allowed by the above supposition for extraordinary conditions is but about fifty per cent. of the greatest anticipated flow, it will, except in extreme cases, be found ample. It should not be increased without reason, as this will impair the efficiency and cleanliness of the system during the ordinary use.

The formula used in preparing the diagram is that of Weisbach.

$$v=\frac{\sqrt{2gh}}{\sqrt{1+e+c\times\frac{l}{d}}} \qquad \text{(Eq. 2)}$$

in which h=head.

l=length of pipe in feet.

d=diameter of pipe in feet.

v=velocity in feet per second, when running full or half full.

c=coefficient of friction in pipe.

e=coefficient of resistance for entrance.

$$c=.01439+\frac{.016921}{\sqrt{v}}$$

e is assumed at an average of .505

The coefficient of resistance for entrance (e) is not applicable to continuous, long pipes, fed at various points throughout their length. As it is usual, however, to place man-holes at intervals along the sewer, the coefficient may properly be considered.

Since in the general formula

$$v = B\sqrt{rs} \qquad \text{(Eq. 1)}$$

in which v = velocity,

B = coefficient determined by experiment.

$$r = \frac{\text{area}}{\text{wetted perimeter.}}$$

$$s = \frac{\text{head}}{\text{length}} = \text{sine of slope.}$$

we have $r = \dfrac{\text{area circle}}{\text{circumference}}$ when the pipe is running full.

and $r = \dfrac{\frac{1}{2}\text{ area circle}}{\frac{1}{2}\text{ circumference}}$ when the pipe is running half full.

The velocity (v) is the same when the depth of flow is one-half the diameter as when the pipes are running full.

When the depth of flow is half the diameter the discharge in cubic feet per minute becomes

$$\frac{1}{2}\left\{ v \times 60 \times \frac{\pi d^2}{4} \right\} = 30v\frac{\pi d^2}{4} \qquad \text{(Eq. 3)}$$

Assuming the sewage of twenty-four hours to be discharged in sixteen hours, the daily capacity in gallons of a sewer under the conditions named, becomes

$$\frac{1}{2}\left\{ v \times 60 \times \pi\frac{d^2}{4} \right\} \times 60 \times 16 \times 7.48$$

in which v = velocity in feet per second.

d = diameter in feet;

or,

$$\frac{1}{2}\left\{ \frac{V}{60} \times 60 \times \frac{\pi\left(\frac{D}{12}\right)^2}{4} \right\} \times 60 \times 16 \times 7.48 \qquad \text{(Eq. 4.)}$$

in which V = velocity in feet per minute.

D = diameter in inches.

The expression reduces to the following form:

$$\text{Daily capacity in gallons} = 19.5822 \times V D^2 \quad \text{(Eq. 5.)}$$

If we represent the inclination and discharge graphically, by the abscissa and ordinate, respectively, of a co-ordinate system, the value of the ordinate corresponding with any abscissa can be determined from the above formulæ. If we make the diameter constant, and compute for varying grades and velocities, the ordinates will determine a curve representing pipe of the assumed diameter. If we make the velocity constant, and compute for varying grades and diameters, the ordinates will determine a curve representing the assumed velocity.

In the equations of velocity and discharge, if we make D constant (the pipes running half full), the hydraulic mean radius becomes constant, and the discharge varies as the square root of the sine of the angle of inclination, or as $\sqrt{\frac{1}{100}}$, $\sqrt{\frac{2}{100}}$, etc., and the equation may be reduced to the form:

$$\text{Discharge} = \sqrt{\textit{constant} \times \frac{1}{100}}, \text{ etc.}$$

The curves of diameter are, therefore, parabolas and pass through the zero of the co-ordinate system.

When the depth of flow is equal to half the diameter,

$$r = \frac{\frac{1}{2}\,(D^2 \times .7854}{\frac{1}{2}\,(D \times 3.1416} = \frac{D}{4}$$

$$v = B\sqrt{\frac{D}{4}\,s}$$

$$\text{Discharge} = 19.5822\ D^2 B\sqrt{\frac{D}{4}\,s}$$

$$= 19.5822\ B\sqrt{\frac{D^5}{4}\,s}$$

or, the discharge varies as the square root of the fifth power of the diameter.

The use of the table will best be illustrated by a few examples:

(1) *Required*, the limiting length of a sewer six inches in diameter, accommodating fifteen persons using seventy gallons each, for each 50-foot lot, the grade to be .5 per 100.

Solution. Note the point at which the curve representing diameter of sewer six inches, is intersected by the perpendicular line of fall in 100=.5 From this intersection trace a line to the left, preserving the same relative distance from the parallel lines on either side, until the vertical representing seventy gallons per diem per capita is reached, then to the left and downward, preserving the same relative distance from the diverging lines on either side to the column of Tributary Population, then horizontally to the left, preserving the relative distance, as before, to the vertical representing sixty persons tributary to each 100 feet of sewer (fifteen persons for each lot fifty feet in width), then downward and to the left, preserving the same relative distance as before, to the intersection with the column of lineal feet when the distance required is read, being in this case about 2,500 feet.

Incidentally we determine that the total discharge is 105,000 gallons per day, and the total assumed population 1,500, by noting the point at which the line we traced crossed these columns in the table.

(2) *Required*, the size of outfall necessary to discharge the sewage of 12,500 lineal feet of tributary lateral sewers, allowing ten persons for each twenty-five foot lot, and seventy five gallons per diem per capita.

Solution. Starting at the left hand column in the table at 12,500 lineal feet, follow the diagonal line upward and to the right to the vertical line of eighty gallons, thence horizontally to the right across the column of Tributary Population (which is determined to be 10,000), thence diagonally upward and to the right to the vertical line of seventy-five gallons (midway between seventy and eighty), thence horizontally to the right, when we note that the total daily discharge will be 750,000 gallons, and that it will require a sewer of the following dimensions:

20 inches in diameter...... .05 per 100 grade.
18 inches in diameter...... .11 per 100 grade.
15 inches in diameter...... .26 per 100 grade.
12 inches in diameter...... .75 per 100 grade.
10 inches in diameter......1.88 per 100 grade.

But from the curves of velocity we note that the 20-inch sewer laid at a grade of .05 per 100 has a velocity less than 120 feet per minute, which is inadmissible, and the 18-inch sewer laid at a grade of .11 per 100 has a velocity of scarcely 120 feet per minute (118 by arithmetical computation), and the minimum velocity we have assumed in Table XII is 129 feet per minute. The conditions will be met by either of the other three sewers, and the velocity in each case will be approximately 170 feet, 240 feet and 390 feet per minute.

(3) *Required*, the size of outfall sewer to accommodate a population of 100,000, using seventy gallons per diem per capita.

Solution. We observe that 15,000 is the greatest number provided for in the column of Tributary Population. At the right, however, will be found a supplementary diagram, in which the gallons are ten times the corresponding number of gallons in the main diagram. We can, therefore, use that part of the diagram to the left of the column marked "total gallons per diem" in connection with the supplementary table, by multiplying "lineal feet of sewer" or "tributary population" by 10. Starting thus at 10,000 in the column of tributary population, trace the line upward and to the right, to its intersection with the vertical representing ninety gallons, thence horizontally to the supplementary table, we read 9,000,000 gallons daily, and continuing the horizontal line we cross the sewers of

54 inches in diameter at .06 per 100 grade.
48 inches in diameter at .11 per 100 grade.
40 inches in diameter at .26 per 100 grade.
36 inches in diameter at .44 per 100 grade.

Either one of these sewers laid at the grade indicated will fill the conditions.

(4) *Required*, the number of people using seventy-five gallons per diem each that can be served by a 4-inch house drain, laid at a grade of 2 in 100.

Solution. Tracing a line from the point where the curve of 4-inch diameter is intersected by the vertical of grade per hundred=2, to the left and horizontally to the vertical of seventy-five gallons, thence to the left and downward we read 1,000 people.

Other uses of the diagram will readily suggest themselves. Of the four quantities,

Total gallons per day,
Velocity,
Fall in 100,
Diameter,

any two being given, the other two can be determined by inspection of the diagram.

Let us take that portion of the city of Schenectady, N. Y., lying between the Erie Canal and the Mohawk River, and tributary to the Front street sub-main sewer, as an example illustrating the use of the table in proportioning a complete system. The map will be found in front of book.

The territory has at present a population of 5,000, distributed with tolerable uniformity. The aggregate length of the sewer is 15,065 feet, giving thirty-three persons for each 100 feet of sewer. In this case it is not likely that the territory will ever reach a greater density of population. We will assume, however, that it may reach a density expressed by fifty persons for each 100 feet of the sewer, and will assume a discharge of seventy-five gallons per diem per capita.

First, arrange the distances of the various branches so that the aggregate length of sewer tributary to any point can readily be seen on inspection, as follows:

From corner Washington Ave. and Union St. to corner of State and Church Streets	860	
Church—Union to State	400	
	1260	
State—Church to Ferry	440	
State—Canal to Ferry	530	
	2230	2230
Ferry—State to Liberty		245
Liberty—Erie Canal to Ferry		730
		3205
Ferry—Liberty to Union		290
Washington Ave. and Union to Church	625	
Church—Front to Union	450	
	1075	
Union—Church to Ferry	425	
	1500	1500
		4995
Ferry—Union to Front		725
Washingon Ave. and Front to Ferry		1200
		6920
Front—Ferry to College		935
		7855
College—Liberty to Union	350	
Union—Ferry to College	830	
College—Union to Green	665	
	1845	
Green—Ferry to College	825	
Green—R. R. to College	175	
	2845	
College—Green to Front	560	
	3405	3405
		11260
Front—College to John		420
John Street		740
		11420
Front—John to Jefferson		255
Jefferson	600	
Madison	200	
	800	800
		13475
Front—Jefferson to Monroe		250
		13725
Monroe		500
Front—Monroe to outlet main		840
		15065

If we assume the smallest laterals to be six inches in diameter and the grade to be .5 per 100, we see from the diagram that their limiting length in this case is 2,800 feet. This size will, therefore, suffice until their aggregate length exceeds 2,800 feet. Should the grade be increased, however, at this point the 6-inch sewer may be extended still farther.

Inspecting the figures made above, we determine that the size must be increased after the junction of the Liberty street and Ferry street sewers. Assuming the grade immediately below this point to be .4 per 100, we determine from the diagram that an 8-inch pipe will suffice up to an aggregate length of 5,000 feet. Inspecting the summation above, we determine that this is reached after the Ferry street sewer receives the Union street sewer and its tributary branches. From this point, then, the size must be increased. Assuming the grade from this point to be .28 per 100, we determine from the diagram the limiting length of a 10-inch pipe to be 7,500 feet. From the summary of length we see that this would require a still greater increase of size, the grade being the same, 355 feet above the junction of the College street sewer. A man-hole at this point is not contemplated, and a change in size between man-holes is not advisable; we will, therefore, increase the grade, retaining the same size. Recurring to the diagram, we see that the required grade, the diameter being ten inches and the aggregate length being 7,855 (or, in round numbers, 8,000), is .32 per 100. The grade, from a point 355 feet above College street, will, therefore, be increased to .32 per 100.

Taking up, now, the branches tributary to the College street sewer, and remembering that our limiting distance for the smaller laterals is 2,800 feet, we note that the size must be increased at the junction of the Green street sewer. It is evident that from this point to the Front street main an 8-inch pipe will be ample.

Uniting the College street sub-main with the Front street main, we have an aggregate length of 11,260 feet. Assuming the grade below to be .32 per 100, the diagram gives the limiting length for a 12-inch sewer as 12,700. This is reached when we add the Madison street sewer and tributaries. From this point the grade required to reach Monroe street (13,725 feet, aggre-

gate distance), we find by the diagram to be .36 per 100, and to reach the main outlet (15,065 feet, aggregate distance), .44 per 100, the size of sewer being maintained at twelve inches. Incidentally, we note that the velocity at this point is two hundred feet per minute, and the daily discharge 565,000 gallons.

The computations can be made with the same facility, commencing at the outlet and proceeding toward the dead ends. A comparison of the results obtained from the diagram by different persons show them to agree within about one per cent., an error of no consequence when the data cannot be stated with precision.

It is proper to state that Baldwin Latham, in calculating the tables on which the diagram is based, has assumed a value for h equal to the velocity in feet per second in each case, to simplify the computations. The tables are, therefore, strictly correct only when the length in feet equals the velocity in feet per second, multiplied by the denominator of the fractional inclination. Thus:

6-inch pipe, grade 1 in 200	490 feet.
6-inch pipe, grade 1 in 100	355 feet.
12-inch pipe, grade 1 in 400	980 feet.
12-inch pipe, grade 1 in 200	710 feet.
24-inch pipe, grade 1 in 1000	2166 feet.
24-inch pipe, grade 1 in 5000	1575 feet.

Comparison of Various Standard Formulæ.—Some authorities prefer to use other formulæ than those of Weisbach, on which the diagram is based. A comparison of the results obtained from various standard formulæ is presented below.

The following are some of the standard formulæ used by the best authorities:

Baldwin Latham, Weisbach, ...

$$v=\frac{\sqrt{2gh}}{\sqrt{1+e+c\frac{l}{d}}}$$

$$\text{Kutter, ------}v=\left\{\frac{\left(41.66+\frac{1.8113}{n}+\frac{.002807}{S}\right)}{\left(1+(41.66+\frac{.002807}{S})\frac{n}{\sqrt{R}}\right)}\right\}\sqrt{RS}=C\sqrt{RS}$$

in which v=mean velocity in feet per second.

C=coefficient of mean velocity.

S=sine of slope.

R=hydraulic mean radius.

n=coefficient of resistance to flow, determined by experiment.

$$\text{Beardmore, ---}v=100\sqrt{RS}$$

$$\text{Eytelwein, ----}v=93.4\sqrt{RS}$$

$$\left.\begin{array}{r}\text{Box,}\\ \text{Shone,}\end{array}\right\}v=\frac{\left\{\frac{(3d)^5\times H}{L}\right\}^{\frac{1}{2}}}{373.98a}$$

in which d=diameter in inches.

H=head in feet.

L=length in yards.

a=sectional area in square feet.

$$\text{Darcy, ----}v=\sqrt{\frac{d^2H}{.00371(d+1)L}}$$

in which d=diameter in inches.

H=head in feet.

L=length in feet.

From these formulæ Table XIV has been computed.

TABLE XIV.

Comparing the Discharge in Various Cases as Given by Different Standard Formulæ.

Diameter of Sewer in Inches.	Grade per 100.	BALDWIN LATHAM.	KUTTER. $n=$ .011	KUTTER. $n=$ .013	KUTTER. $n=$ .015	BEARDMORE.	EYTELWEIN.	SHONE AND BOX.	DARCY.
		DISCHARGE IN CUBIC FEET.							
6	.50	28.81	25.68	21.1	16.80	29.4	27.69	27.0	30.9
6	2.00	60.17	51.36	42.2	33.60	58.8	55.38	54.2	61.8
12	.25	115.40	132.00	102.0	83.40	118.0	110.90	108.4	128.7
12	1.50	294.90	318.00	272.0	203.85	288.4	270.90	......	315.0
18	.14	236.50	294.00	234.0	191.97	243.0	229.00	223.0	264.7
18	1.00	660.90	762.00	618.0	513.00	649.0	612.00	......	718.8
24	.10	408.50	516.00	420.0	358.00	421.5	398.00	......	472.3
24	.50	958.30	1,170.00	954.0	801.00	942.6	888.00	......	1,056.0
		PERCENTAGE RELATION.							
6	.50	100	89	73	68	102	96	94	107
6	2.00	100	85	70	56	98	92	90	103
12	.25	100	114	88	72	102	96	94	112
12	1.50	100	107	92	69	98	92	......	107
18	.14	100	124	99	81	103	97	94	112
18	1.00	100	115	94	79	98	93	......	109
24	.10	100	126	103	88	103	98	......	116
24	.50	100	123	100	83	98	93	......	110

It will be observed that, with the exception of Kutter's formula, the results above given, though not equal, run approximately parallel.

Kutter's formula gives much smaller values for sewers of small diameter, and much larger values for sewers of large diameter. When $n=15$, the values given by Kutter and Latham are approximately equal for a sewer five feet in diameter. This value of n, however, is not applicable to vitrified pipe sewers, well constructed, unless it be on very sharp curves, where ordinarily the work is less perfect

Loss of Head on Curves.—An increase of inclination should be given around curves, both to overcome the increased friction due to angular change in direction, and also for the reason that, as ordinarily laid, there is a slight opening of the joints in the outward circumference and greater liability to stoppage from articles lodging crosswise.

The allowance indicated by theory for the increase of friction on curves is not sufficient, for the reason that pipes are not usually laid so truly to line or grade as when laid in straight lines, and, aside from the increased friction due to the angular change in direction, we may properly increase the coefficient of resistance to flow in the pipe.

The following is Baldwin Latham's modification of Weisbach's formula for loss of head due to angular friction:

h=head necessary to overcome angular friction.

v=velocity in feet per second.

a=angle in degrees.

r=radius of pipe.

b=radius of the bend.

$2g=64.38$

c=coefficient.

$$h=c\times\frac{a}{90}\times\frac{v^2}{2g}\quad\text{or,}$$

$$h=\frac{c}{579.4}\times a\times v^2 \qquad \text{(Eq. 6)}$$

In which $c=.131\times 1.847\left\{\frac{r}{b}\right\}^{\frac{7}{2}}$

For

$\frac{r}{b}$=.1	.2	.3	.4	.5	.6	.7	.8	.9	.10
c=.131	.138	.158	.206	.294	.440	.661	.977	1.408	1.978

Assuming a 6-inch sewer laid with a curve of fifty feet radius, the angle of the curve being sixty degrees, or its length 52.4 feet, and the velocity above the curve to be five feet per second, the increased head necessary to overcome friction due to angular change in direction is, according to equation six, less than one-eighth of an inch. In no case which could possibly occur in curves of a proper radius will the formula give more than a small fraction of an inch as the value of h. This is too small to be considered in work of this class.

In proposing a formula for the increased head or inclination required for curves as ordinarily laid in sewer work, we may, therefore, disregard the effect of angular change in direction.

If, however, we assume that the increased roughness of the pipe would increase the coefficient n, as given in Kutter's formula, from n=.011, its value as given for plaster of cement with $\frac{1}{3}$ sand, to n=.013 and n=.015, its value as given for brick work and terra cotta pipes with imperfect joints and in bad order, we have from Kutter's formula, by computation, the following table:

TABLE XV.

Showing Increased Frictional Head Required for Curves in Various Cases.

Diameter.	Coefficient of Resistance.	Velocity.	Percentage Relation of C.*	$v=2\frac{1}{2}$ feet per second.		$v=5$ feet per second.	
				Grade per 100.	Loss of Grade per 100.	Grade per 100.	Loss of Grade per 100.
6 inch	$n=.011$	$87.35\sqrt{RS}$	100.00	.65	...	2.62	....
" "	$n=.013$	$69.77\sqrt{RS}$	79.86	1.02	.37	4.10	1.48
" "	$n=.015$	$57.15\sqrt{RS}$	66.00	1.53	.87	6.12	3.50
12 inch	$n=.011$	$105.74\sqrt{RS}$	100.00	.22	...	.89	....
" "	$n=.013$	$84.92\sqrt{RS}$	80.31	.34	.12	1.38	.49
" "	$n=.015$	$70.8\sqrt{RS}$	66.00	.49	.27	1.99	1.10
18 inch	$n=.011$	$116.2\sqrt{RS}$	100.00	.12	...	.49	....
" "	$n=.013$	$94.7\sqrt{RS}$	81.45	.18	.06	.74	.25
" "	$n=.015$	$79.0\sqrt{RS}$	68.00	.26	.14	1.06	.57

* According to Kutter.

In the columns of loss of grade per 100 feet can be found the increased fall necessary, under the supposition that, on ordinary curves, n is increased from .011 to .013, and on sharp curves from .011 to .015.

It will be observed that when $n=.013$ the value of C is decreased to about eighty per cent. in all cases. Recurring to the simpler formula of Weisbach, which, for the ordinary range of diameter and velocity, becomes, approximately,

$$v=100\sqrt{R\ S}$$

We may write for ordinary curves,

$$v=80\sqrt{R\ S'}$$

in which $S'=\dfrac{h'}{l}=$slope required.

From the preceding equations we have

$$S=\frac{v^2}{(100)^2 R}$$

$$S'=\frac{v^2}{(80)^2 \mathrm{R}}$$

Or, since in each case the hydraulic mean radius when the sewer is half full $=\frac{d}{4}$

$$S'-S=\frac{v^2}{1600d}-\frac{v^2}{2500d}$$

$$H=h'-h=\frac{v^2\,l}{4444d}=\text{loss of head required.} \qquad \text{(Eq. 7)}$$

In pipe sewers, however, the roughness is somewhat dependent on the ratio of the radius of the curve to diameter of the pipe.

Empirical Formula.—The following formula will give good results in pipe sewers:

$$H=\frac{v^2\,l}{4000d}\left\{1+\frac{10d}{r}\right\} \qquad \text{(Eq. 8)}$$

in which $v=$ velocity in feet per second.
$l=$ length of curve in feet.
$d=$ diameter of sewer in feet.
$r=$ radius of axis of curve in feet.
$H=$ loss of head for curve in feet due to increased roughness.

H in the above formula does not represent the total fall required for the curve, but the excess of fall necessary over that if the sewer were straight, and the flow had an equal velocity.

CHAPTER VII.

MATERIAL AND ACCESSORIES.

Sewer Pipes.—Salt-glazed, vitrified earthenware is the best material thus far produced for sewer pipes. It forms a smooth, impervious conduit, is not affected by the sewage, and is practically indestructible. It is manufactured in all sizes, from two inches to two feet in diameter, and in convenient forms for special purposes. The pieces are usually either two or three feet in length. They are either made with a "bell" at one end for holding the "spigot" end of the adjoining piece in laying, or as simple cylinders, with a separate collar for making the joint. The socket and spigot pipe is usually preferred. Pieces with Y branches should be placed wherever a lateral sewer or a house drain is to be connected with the sewer.

Tests of twelve-inch sewer pipe were made at Boston by Chief Engineer W. H. Bradley, with the following results:

"The pipes were three feet long and without sockets, except as noted.

"The crushing test was made by bedding the pipes, horizontally, half their depth in sand and crushing them by a weight applied uniformly along the length, on the top; figures are pounds per foot of length (average of three pipes).

"The breaking test was made by supporting ends of pipes on two blocks two feet six inches apart and applying weight at centre; figures are total weight (one test).

"The abrasion test was made by applying a section ½ inch square, loaded with 20 lbs., to a revolving grindstone three feet in diameter, kept wet and clean; figures are revolutions necessary, 1st, to remove glazing; 2d, to grind away 1-10 of total thickness including glazing (average of two tests)."

TABLE XVI.

Tests of Sewer Pipe Twelve Inches in Diameter.

Owners and Kind of Pipe.	Weight in Lbs. per ft.	Thickness in Inches.	Specific Gravity.	Crushing Weight, lbs. per foot length.	Breaking Weight, lbs. on 2 ft. 6 in. span.	Abrasion. Glazing.	Abrasion. 1-10 Thickness.
Otis & Gorsline, Rochester, N. Y.	47.7	1.16	2.26	2807	4299	25	517
D. L. King, Secretary, Akron Co., Ohio	40.3	0.99	2.25	1891	3992	30	398
D. W. Lewis, Agent, Tallmage Co., Ohio	42.0	1.03	2.48	2107	4606	33	600
Hill Sewer Pipe Co., Ohio	40.5	1.00	2.32	2286	4299	25	535
T. W. Carter, Agent, Buckeye Co., Ohio	40.5	1.01	2.31	2140	4299	......	......
Wm. Nelson, Jr., N. Y. City, Scotch Pipe	43.0	1.12	2.19	1875	3982	9	32
Portland Stoneware Co., Salt Glazed	41.1	1.16	......	2495	......	14	187
" " " Slip "	40.6	1.16	2.11	4652	4913	13	35
G. W. Rader, N. Y. City, Salt Glazed	40.4	1.04	......	1880	......	75	793
" " " Slip Glazed	40.0	1.10	2.17	2052	4299	12	90
Marcellus Day, Boston, Portland Cement	63.0	......	......	2316	5836	......	......
S. Richardson, Philadelphia, Carbonized Stone, 12 by 18¾ inches	81.1	1.00 to 1.75	2.32	2021	......	......	......

The capacity of vitrified salt-glazed sewer pipe to resist abrasion is very marked.

Hand-Holes.—A "hand-hole" is a piece of pipe provided with a detachable section. See Fig. 2. These hand-holes afford the means of removing obstructions without breaking the pipe. They are usually laid at intervals of about one hundred feet. Their use may be dispensed with and the sewer may be opened when necessary by removing the cap from a Y branch.

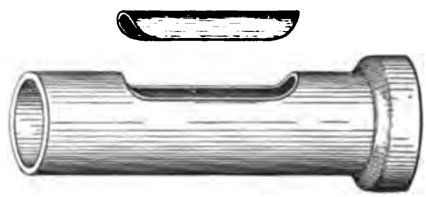
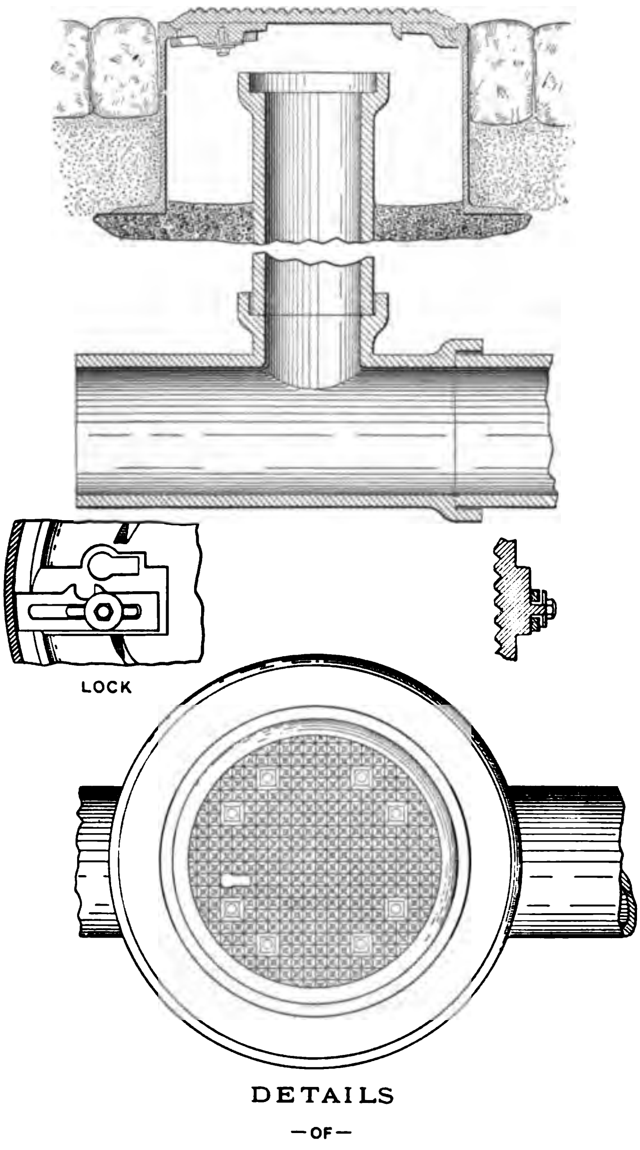


FIG. 2.

Lamp-Holes.—At intervals a T should be placed in the sewer and a stand-pipe carried to the surface, forming an opening where the action of the sewer may be observed. See Plate I. Part of them may stop just beneath the pavement and be covered with a light casting, shown in Plate I, and at longer intervals part of them may be carried to the surface and protected with a cast iron cover.

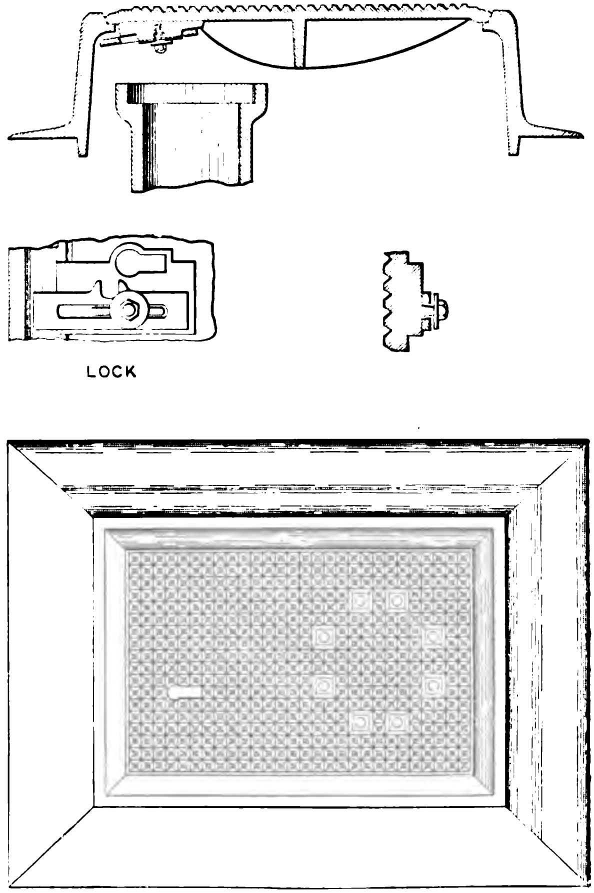
Fresh Air Inlets.—These will answer in place of manholes in some cases when the distance between the junction of two or more sewers is considerable. They afford equal facilities for inspection, and have the advantage of preserving the flow of sewage in its proper sectional form and precluding the possibility of deposit. They are, however, not available as points from which cleaning tools can be inserted into the sewer. They should be covered with a perforated cast-iron cover, similar to that shown in Plate II, to assist in the ventilation of the sewer. They can be very cheaply constructed.

They should always be thus brought to the surface when it is proposed to extend a line of sewer in the near future, and can be built up from a T or from an elbow, as shown in Plate II, and can then be used temporarily for flushing the sewer with a hose from the city hydrants.



DETAILS
—OF—
FRESH AIR INLET.

PLATE III.



DETAILS
—OF—
FRESH AIR INLET.

In Plate III is shown a style of cover suitable for use in unpaved streets, where a larger chamber is needed for collecting the street detritus which works through the perforations.

Man-Holes.—Where two or more sewers unite a man-hole should be placed. See Plate V. They should be built of selected, hard brick, laid in cement mortar, plastered inside and outside, and surmounted by a heavy cast-iron cover. It is very difficult to make a proper connection between two pipe sewers of large size by the use of the ordinary Y branch. The manholes are also required for purposes of inspection, repair, removal of obstructions, and ventilation.

The advisablity of omitting man-holes has been considerably discussed of late, but in cases where they have been omitted it has usually resulted in their being built subsequently. It is not advisable, however, to construct them in the first instance, except where two or more sewers join.

Flush-Tanks.—All dead ends should be supplied with automatic flushing tanks, the size of which should be proportioned to the size of the lateral. They should be built of selected, hard brick and cement mortar, and plastered inside and outside, and surmounted by a heavy iron cover. They are usually supplied with water from the street mains through an ordinary service pipe of small size, and the admission of water is controlled by an ordinary lever handle stop-cock. They are built in various forms and will be more particularly described in the chapter on Flushing and Ventilation.

Y Branches.—The usual form of Y branch is shown in Plates I and VII. It consists, essentially, of a cylinder of smaller diameter intersecting the main pipe at an angle of about thirty degrees, measured on the side of the intersection toward the socket end of the main pipe. The axes of the intersecting cylinders meet in a common point. The Y branch can, therefore, be turned to the right or left with equal facility.

Another form of Y branch is shown in section in Plate I. It consists of an intersecting frustum of a cone, the diameter of whose base is equal to the diameter of the main pipe and common with it. It is claimed for this branch that it induces a more perfect ventilation by entirely withdrawing the air from the crown of the main sewer.

It is open to the objection that it does not preserve the proper cross-sectional form of the stream but allows it to spread out laterally into the branch itself, thus breaking up the continuity of the flow, decreasing the velocity, and tending to the formation of eddies and deposits.

The comparative effect of the two styles of Y branch upon the cross section of the stream when the pipes are flowing half full is shown in Plate I.

CHAPTER VIII.

SPECIFICATIONS AND CONTRACT.

Letting the Contract.—Having determined upon the plan for a system of sewers, the sizes of the pipes required for the different lines, and the details of the accessories, the next step is to arrange for constructing the sewers.

The usual way is to advertise for bids for constructing the work according to the plans and specifications prepared by the engineer. A description of the work and approximate quantities—subject to change by the engineer—may be given either in the notice to contractors, or in an estimate filed with the detailed plans and profiles, which have been prepared to accompany the specifications. All drawings should be carefully made to scale, and full descriptions of them should be written out, so that every point may be made plain and nothing left to be inferred.

As a guide in this work, a few blank forms are presented, which can be modified to suit the requirements of particular cases. They have all been tested in actual work.

[Form for Advertisement]

NOTICE TO CONTRACTORS.

Sealed proposals will be received at the office of the Sewer.........
........................., in the City of...................................,
until....o'clock........, on the..........day of................., 188..,
for constructing sewers in..
....

Forms of proposals, copies of the specifications, and instructions to contractors may be obtained of the Engineer; and the plans and profiles may be seen at his office.

Each bid must be accompanied by a deposit of $..........as a guarantee of the good faith of the bidder.

The Committee reserve the right to reject any or all bids.

Address, SEWER COMMITTEE,

....

....

....

Engineer.

[Instructions to Contractors.]

TO CONTRACTORS.

1. All bids must be made upon the printed forms, to be obtained at the office of the Engineer, and enclosed in a sealed envelope, directed to the Engineer of Sewers,.., and endorsed upon the outside of the envelope, *Proposal for Constructing Sewers in the City of*..

2. Each bid must be accompanied by a deposit of..............Dollars, to be left in the hands of the City Clerk, subject to the conditions specified in the proposal hereto annexed, as a guarantee of the good faith of the bidder.

3. Bids shall state the price per lineal foot of pipes of each size laid, as herein specified, and for the various depths of trench named, also for all other items enumerated in the schedule opposite, which price shall be in full for all labor and materials required for the complete execution of the work.

4. All prices must be written in words, and also stated in figures.

5. The place of residence of each bidder must be given after his signature, which must be written in full. When firms bid, the individual names of the members shall be signed in full, and the firm name added.

6. The name of the contractor must be filled in the blanks left for that purpose.

7. The City of..reserves the right to reject any or all bids.

8. Bidders are requested to be present at the opening of the bids.

[Form of Proposal.]

PROPOSAL.

To the Mayor and Common Council of the City of..............................

GENTLEMEN: The undersigned hereby propose to furnish all of the materials and do all of the work required to complete such amount of the above mentioned work as shall be awarded to the undersigned by the City of......................................., in a first-class manner, and in accordance with the specifications hereto annexed, and the plans and drawings of the same on file in your Engineer's office, at the following prices, viz.:

ITEMS.	Price in Figures.	Price in Words.
Price per lineal foot for furnishing and laying 18-inch pipe, including Ys, branches, detachable covers, and cement joints		
Price per lineal foot for furnishing and laying 15-inch pipe, including Ys, branches, detachable covers, and cement joints		
Price per lineal foot for furnishing and laying 12-inch pipe, including Ys, branches, detachable covers, and cement joints		
Price per lineal foot for furnishing and laying 10-inch pipe, including Ys, branches, detachable covers, and cement joints		
Price per lineal foot for furnishing and laying 8-inch pipe, including Ys, branches, detachable covers, and cement joints		
Price per lineal foot for furnishing and laying 6-inch pipe, including Ys, branches, detachable covers, and cement joints		
Price per lineal foot for all excavation and back-filling under 6 feet deep		
Price per lineal foot for all excavation and back-filling 6 feet or over, and under 8 feet		
Price per lineal foot for all excavation and back-filling 8 feet or over, and under 10 feet		
Price per lineal foot for all excavation and back-filling 10 feet or over, and under 12 feet		
Price per lineal foot for all excavation and back-filling 12 feet or over, and under 14 feet		
Price per lineal foot for all excavation and back-filling 14 feet or over, and under 16 feet		
Price per lineal foot for all excavation and back-filling 16 feet or over, and under 18 feet		
Rock Trench per lineal foot, per foot in depth		
Price per lineal foot for repaving		
Man-holes, complete, each		
Lamp-holes, " "		
Flush-Tanks, " "		
Price per ton for iron pipe, laid with lead joints, complete		
Rock work, price per cubic yard		
Embankment, price per cubic yard		

Extra work according to Engineer's estimate.

And......hereby agree to enter into a contract within five days from the date of your acceptance of this proposal, to finish and complete said work (by the.......day of............................), according to the form hereto attached, and the plans and specifications on file in the office of the Engineer, under which the bid was made, and will furnish such sureties for the faithful performance of such contract, the payment for materials contracted for, and for the payment of laborers' wages, and liens which may arise therefrom, as shall be approved by the City Council.

In default of the performance of any of the conditions on.......part to be performed, the sum of....................................Dollars, which............have this day deposited with the City Clerk, shall, at the option of the said City Council, be absolutely forfeited to the City of ....; but otherwise said sum of ....Dollars shall be returned to......

Dated at................................, the.............day of ...., 188..

[Contractor's Signature,]...

....

....

....

....

[P. O. Address,]..............................

No...........   [State,].................

[Form for Receipt.]

$...........   ....188..

RECEIVED of...,

City Clerk of the City of..,

....Dollars, being the amount deposited with the above proposal.

No............   ....

[Form for Receipt.]

$............ ....188..

RECEIVED of..,
on behalf of the City of..,
the sum of..Dollars, subject to the
conditions named in........proposal to the Mayor and Common Council
for...
.........................of even date herewith, which sum, if the same
shall not be declared forfeited by said Common Council, will be returned
to said..., upon the
surrender of this receipt.

No............ ....

City Clerk.

[Form for Specifications and Contract.]

ARTICLES OF AGREEMENT

Between the City of..,
party of the first part, and...,
Contractor, party of the second part, for building..............................
..........................*Sewers in*...
....

THIS AGREEMENT, made and entered into this................day of
..........................., in the year one thousand eight hundred and
..................., by and between the City of.....................,
party of the first part, and ....,
Contractor.., party of the second part.

Witnesseth, Whereas, The City of.............................., in the
State of........................., by virtue of the authority vested in the
Common Council by the Legislature of the State of...................,
and by the Charter and Ordinances of the City, agree to let unto the said
...., Contractor.. the work of
constructing certain................................Sewers, as per plans
and profiles of the work on file in the office of the Engineer of Sewers.

Now, Therefore, in consideration of the payments and covenants hereinafter mentioned to be made and performed by said party of the first part, the said..hereby covenants and agrees to do the work above mentioned in a substantial and workmanlike manner, in conformity with the plans, profiles, and specifications of such work on file in the office of the Engineer, in strict obedience to the directions which may from time to time be given by the said Engineer or his duly authorized assistants, and in accordance with the following specifications:

SPECIFICATIONS FOR SEWERS

In the City of..

1. The sewers shall be constructed of first quality vitrified, salt-glazed sewer pipe, sound and well burned throughout their thickness, impervious to moisture, of smooth and well glazed exterior and interior surfaces, free from cracks, flaws, blisters, fire-checks, and all other imperfections, circular in the bore, of true form in their lengths, whether straight or curved, internally of the exact specified diameter, and of uniform standard thickness.

2. All pipe shall be socket pipe, with true and circular sockets, concentric with the bore of the pipe, and shall be furnished in pieces two feet long. For all junction pieces, a well fitted vitrified stopper shall be furnished, without charge.

A Y branch connection, of four inches in diameter, shall be provided opposite every lot of......feet in width in front of which it passes.

IRON PIPE.

3. Iron pipe shall be used where the sewer runs under or through waterways—either natural or artificial—or under a railroad, or wherever it is deemed necessary by the Engineer. The joints shall be of lead, properly caulked. The lengths of pipe, their diameter and thickness to be as directed by the Engineer. The weight of each pipe shall be plainly marked on it before leaving the factory.

The iron pipe shall be paid for by the ton, laid in place with joints complete.

4. The sewers shall be located on the lines shown on the plans of the work, and will be staked out by the Engineer. This line, whenever practicable, will be on the centre line of the street. The committee, however, reserve the right to move the line of sewers to the right or left whenever obstructions are met which render a change of line desirable.

5. The contractor will be required to preserve all stakes and bench marks until permission is given by the Engineer to remove them.

EXCAVATION.

6. All excavation shall be by open cut from the surface. No tunneling will be allowed, except written permission be previously obtained from the Engineer.

7. The contractor will be required to keep the sides of the excavation vertical, by bracing or otherwise; but no allowance will be made therefor unless the same is left in the trench by written order of the Engineer.

8. The excavation, at the bottom, is to be made and shaped as nearly as possible to fit the lower half of the pipe to be laid, with holes cut at the joints for the sockets to rest in, so that the pipe shall have a uniform

bearing on the ground from end to end. The excavation at the joints shall be at least six inches outside of the joints to enable the joints to be perfectly cemented.

9. At the height of half the diameter of the pipe from the bottom, that is, at the height of the greatest horizontal diameter of the pipe, all trenches are to be eighteen inches wider than the greatest diameter of the pipe to be laid therein.

10. The trench shall be dug to within six inches of grade by measurement from the witness stakes on the surface. The last six inches shall be taken out after the grade pegs have been set in the bottom of the trench by the Engineer.

11. The excavations for all man-holes, flush-tanks, and other accessories shall be sufficient to leave at least one foot in the clear between their outer surfaces and the embankment or timber which may be used to protect it.

12. The approximate depth of the cutting will be given by the Engineer before the excavation is begun. Grade and line will be given by the Engineer every 12½ or 25 feet at the bottom of the trench, on stakes to be set by the contractor.

13. In no case, without previous written permission from the Engineer, shall more than........................feet of trench be opened in advance of the completed sewer.

14. The material excavated shall be laid compactly on the sides of the trench and kept trimmed up so as to be of as little inconvenience as possible to the traveling public and adjoining tenants.

15. The contractor shall not obstruct the gutter of any street, but shall use all proper measures to provide for the free passage of surface water along the gutters.

16. The contractor shall provide for all water courses and drains interrupted during the progress of the work, and replace them in as good condition as he found them.

17. The contractor shall keep the trenches free from water during the progress of the work, as no pipe will be laid in water in any case whatever.

PROTECTION OF WATER AND GAS-PIPES, ETC.

18. The contractor shall do whatever may be necessary to keep in position and to protect from injury all water and gas pipes, lamp posts, service pipes, and all other fixtures which may be met with in carrying on the work.

In case any of the said gas or water pipes or other fixtures be damaged, they shall be repaired by the parties having control of the same, and the expense of such repairs shall be deducted from the amounts which may become due the contractor.

PROTECTION AGAINST ACCIDENTS.

19. The contractor shall erect suitable barriers around all excavations, to prevent accidents to passengers on the streets, and shall place and maintain during the night sufficient red lights on or near the work.

20. The contractor shall have charge of, and be responsible for, the entire line of sewers for whose construction he has contracted, until their completion and acceptance.

BACK-FILLING.

21. The earth filled around and on top of the pipes shall be free from stone, and tamped with the utmost care, so as to obtain the greatest compactness and solidity possible. In filling, the earth shall be kept at the same height on both sides of the pipe. The earth shall be rammed in layers of not more than one foot thick up to the surface of the street, and in no case shall the number of men filling be more than twice the number of men ramming.

22. The contractor, without a written permission from the Engineer in charge, is required not to sell, remove, or permit to be removed from the line of the work, before the trench shall have been refilled, any sand, gravel, or earth excavated therefrom which may be suitable and required for refilling.

23. The trench must in all cases be filled to the proper grade with suitable material, free from stones over four inches in diameter. Should there be a deficiency of proper material for refilling the trench, the contractor will be required to furnish the same at his own cost.

REPAVING AND RESTORING STREETS.

24. Where the pavement has been removed, it must be replaced by the contractor and left in as good condition as it was before being removed.

25. As the trenches are filled in and the work completed, the contractor shall remove all surplus material, without additional compensation, to localities not interfering with the regulations of the city, and shall leave all roads and places free, clean, and in good order.

26. All work of restoring the surface of the streets shall be done to the satisfaction of the Superintendent of Public Streets.

EMBANKMENT.

27. Where embankment is necessary to support the foundations of the sewer, or to cover or protect it in any way, it shall be made of the width and slopes as shown on the plan. The surface of the ground receiving the embankment shall be carefully cleared of all muck or unsuitable material, of whatever nature.

The embankment shall then be formed of good loam or gravel, free from all stones over four inches in diameter, and of those below that size

in a proportion not exceeding one part of stone to three parts of earth in any place.

If built to support the foundation of the sewer, the material is to be deposited in layers of not more than six inches in thickness, each layer to be separately compacted by heavy iron rollers, or, where these cannot be used, by heavy pavers' rammers. No breaks, steps, or irregularities in the distribution of material or formation of the layers will be allowed, and the whole embankment is to be carried up evenly so as to make a compact and solid foundation.

PROTECTION OF PROPERTY.

28. The contractor shall. at his own expense, shore up, protect, and make good, as may be necessary, all buildings, walls, fences or other property injured, or liable to be injured during the progress of the work; and the contractor will be held responsible for all damage which may happen to neighboring property from neglect of this precaution, or from any other cause connected with the prosecution of the work.

PIPES—HOW LAID.

29. All pipes over eight inches in diameter shall be laid with a straight edge. One end of the straight edge shall be placed on the nearest grade peg and the other on the flow line of the pipe already laid, and the pipe shall be so adjusted as to be in contact with the straight edge throughout its length.

All pipes less than eight inches in diameter shall be laid in the following manner: A mason's line shall be tightly stretched parallel to the grade and slightly above the sockets of the pipes. This line will be supported over the centre at points not more than twenty-five feet apart. The exact grade for each pipe shall be obtained by measuring down from this line to the invert of the sewer.

30. Especial care must be taken to lay the pipe to the exact grade and line.

31. All pipes, previous to being lowered into the trench, shall be fitted together and matched, so that when jointed in the trench they may form a true and smooth line of pipes. No pipes shall be trimmed in any case. Pipes which do not fit truly shall be rejected.

JOINTS.

32. A gasket of oakum or other material approved by the Engineer shall be pressed into the joint around the entire circumference of the pipe to prevent the entrance of cement to the inside of the pipe. No joint shall be cemented until the gasket of the next joint in advance has been completed.

33. The cement shall be pressed into the space between the socket and spigot so as to entirely fill the space, and the bevel joint at the end of the socket shall be smoothly and evenly made.

Special care must be taken to make perfect joints at the bottom of the pipe.

34. The excavation made for the socket of the pipe shall be filled with sand to support the cement firmly in position. When water accumulates in this excavation it must all be removed before the joint is made.

35. When the joint is completed, great care must be taken not to disturb the pipes.

CEMENT.

36. The cement for filling the joints shall be pure, fresh-ground ....cement, of best quality, with only enough water added to give it the proper consistency, and shall be mixed only as needed for use.

BRANCHES, "T's," ETC.

37. The "Y" branches, "T's," lamp-holes, hand-holes, and man-holes shall be placed at points indicated by the Engineer. They shall not be covered until he has noted and recorded their exact position. The "Y" branches shall be elevated to correspond to the lateral sewers and house drains entering them. They shall be closed with an earthenware cap, and the space above the cap shall be filled with sand, covered with a thin coating of cement.

SPECIAL PIECES.

38. Special pieces, such as Y branches, curves, T's, etc., shall be made according to drawings furnished by the Engineer.

SEWERS TO BE KEPT CLEAN AND FREE FROM WATER.

39. All the pipes must be kept thoroughly clean, and no water will be allowed to flow through them in any case whatever, during the construction of the sewers.

When the trench is left for the night, or the pipe-laying is stopped by rain storms or any other cause, the ends of the sewer must be closed water-tight with a plug and cement, or with bricks and cement, as the Engineer may direct.

40. When running quicksand or other treacherous ground is encountered, the work shall be carried on day and night, should the Engineer so require.

ARTIFICIAL FOUNDATION.

41. Whenever ordered by the Engineer, in writing, the contractor shall excavate to such depth below grade as the Engineer may direct, and the excavation shall be brought to grade with such material as shall be ordered by the Engineer; the extra work to be paid for upon the estimate of the Engineer.

If the contractor excavate below grade without orders, he will be required, at his own expense, to fill the excess of excavation with such material as the Engineer may direct.

Concrete foundations shall be placed under the flush-tanks and man-holes.

ROCK CUT.

42. In rock cut, the rock shall be taken out of the trench to a depth of six inches below the bell of the pipe when laid. The refilling from the bottom of the trench to one foot above the bell of pipe shall be of earth, free from stones, or such material as shall be approved by the Engineer.

When blasting is resorted to for making the excavations, the trench shall be covered carefully on the top and sides with heavy timbers and plank, to prevent fragments of rock from being thrown out.

All damages or injury to persons or property resulting from blasting operations, or from neglect in properly guarding the trenches, must be paid by the contractor; and no compensation to said contractor for losses thus incurred will, under any circumstances, be allowed.

When the excavation for any sewer is made through rock, enough earth must be drawn, in refilling the trench, to replace the volume of stone removed, as the latter will not be permitted to be thrown back. The compensation for this labor must be included in the regular price bid for the sewer.

HAND-HOLES.

43. At intervals of one hundred feet a piece of sewer pipe shall be laid having a detachable section, so that access may be readily obtained to the interior of the pipe. (See drawings.)

LAMP-HOLES.

44. Lamp-holes shall be constructed by placing a six-inch "T" branch vertically in the sewer, and bringing it up to within one foot of the street surface by adding pipes of the same diameter. The top of the lamp-hole shall be protected by a cover, as shown in the detail drawings.

MAN-HOLES.

45. The man-holes shall be constructed of hard brick, laid in cement mortar, and plastered outside and inside with cement mortar. The thickness of the wall shall be eight inches. The form shall be a truncated cone (see drawings). The bottom shall be formed of concrete, and the top of the concrete shall be on a level with the bottom of the sewer pipe, and the top of the cover on a level with the street surface. Particular care must be taken in forming the bottoms of man-holes to make the curves, of tributary sewers, as easy as possible. The top shall be covered with a perforated cast-iron cover, with dust-pan underneath. (See drawings.)

FLUSH-TANKS.

46. Flush-tanks shall be constructed of hard-burned bricks, carefully laid in cement mortar, so as to be water-tight. They shall be plastered outside and inside with cement mortar. (For form, size, and details, see drawings.)

47. The emptying device for the flush-tanks shall be selected by the Commission and shall be properly set by the contractor when building the tank. It will be paid for at manufacturer's prices.

The water supply pipe, within the flush-tank, and extending through the wall and one foot outside of the wall, together with a suitable brass stop-cock for regulating the water supply, shall be furnished by the contractor.

BRICK MASONRY.

48. None but the best quality of whole, sound, perfect brick, burned hard entirely through, shall be used. They are to be culled when delivered upon the ground, and all bats and imperfect bricks are to be immediately removed from the work.

All bricks are to be thoroughly wet immediately before laying. Every brick is required to be laid in a full and close joint of cement mortar, on its beds, ends and sides, at one operation. In no case is mortar to be slushed in afterwards.

CEMENT MORTAR.

49. The cement mortar for man-holes, lamp-holes, and concrete shall be made of best quality of fresh-ground .... cement, and clean, sharp sand, in the proportion of one measure of cement to two of sand. The sand and cement shall be thoroughly mixed dry, and such quantity of water added as to form a paste of the proper consistency. All mortar to be fresh for the work in hand. No mortar that has begun to set will be allowed to be used. Every facility for inspecting and testing the cement shall be furnished by the contractor.

CONCRETE.

50. The concrete used on the work shall be made of stone (broken so as to pass through a two-inch ring) and cement mortar. Stone shall be free from dirt. The cement, sand, and stone shall be mixed in the proportion of one of cement, two of sand, and two of stone.

MATERIALS—HOW FURNISHED.

51. All pipes and other materials shall be furnished by the contractor.

LENGTH OF SEWER.

52. The length of the sewer will be measured on the centre line of the pipe.

INTERPRETATION OF TERMS.

53. Wherever the word "committee" is used in these specifications, it shall be held to mean the "Committee on Sewers" of the Common Council of the City of..

Wherever the word "Engineer" is used, it shall be held to mean the Engineer in charge of the sewers, or his authorized assistant.

Wherever the word "Contractor" is used, it shall be held to mean either any contractor or firm of contractors, or any member of a firm, contracting for work herein specified, or their authorized agent.

GENERAL STIPULATIONS.

54. The contractor shall start the work at and from such points on the line of the sewer as the Engineer may from time to time direct.

55. No pipes or masonry will be allowed to be laid in freezing weather.

56. The contractor shall also do such extra work in connection with his contract as the Engineer may in writing specially direct, and in a first class manner, at a price to be fixed by said Engineer; but no claim for extra work shall be allowed unless the same was done in pursuance of a written order, as aforesaid, to do the work as such and at a price previously fixed, and the claim presented at the first estimate after the work was done.

57. The contractor, upon being so directed by the Engineer, shall remove or rebuild, or make good, at his own cost, any work which the latter shall decide to be deficiently executed.

58. The contractor will be required to observe all City Ordinances in relation to obstructing streets, keeping open passage ways, and protecting the same where exposed, and, generally, to obey all Ordinances, Rules, and Regulations controlling or limiting those engaged on the work.

59. The Engineer shall have the right to make alterations in the line, grade, plan, form, or quantity of the work herein contemplated, either before or after the commencement of the work. If such alterations diminish the quantity of work to be done, they shall not constitute a claim for damages, or for anticipated profits on the work dispensed with; if they increase the amount of work, such increase shall be paid for according to the quantity actually done, and the price or prices stipulated for such work in this contract.

60. If any person employed by the contractor on the work shall appear to the Engineer to be incompetent or disorderly, he shall, on the requisition of the Engineer, be immediately discharged, and such person shall not be again employed upon the work without the permission of the Engineer.

61. The work embraced in this contract shall be begun within....... days after notice so to do shall have been given to the contractor by the

Engineer, and carried on regularly and uninterruptedly thereafter, with such a force as to secure its full completion within........................ thereafter; but should the work be delayed or interrupted by the City, after the service of such notice, the contractor shall be entitled to an extension of time equal to the time of such interruption or delay, which shall be determined by the Engineer; the time of beginning, rate of progress, and time of completion being essential conditions of this contract; and if the contractor shall fail to complete the work by the time above specified, the sum of..........................dollars per day, for each and every day thereafter, until such completion, shall be deducted from the moneys payable under this contract. This sum shall be in addition to any penalties otherwise specified.

62. No charge shall be made by the contractor for hindrances or delay from any cause during the progress of any portion of the work embraced in this contract.

63. No variation from the regular prices named in the proposal will be made or allowed, whether the material through which the trenches are excavated is hard or soft, or whether it is composed of rock, boulders, walls or common earth. The Sewer..............................will not consider itself bound to notify or inform contractors where material that is hard or expensive to excavate occurs, or will be liable to be encountered. Furthermore, no compensation for trenching done in excess of the orders of the Engineer will be allowed.

64. A watchman shall be employed on the work at night whenever in the opinion of the Engineer it shall be necessary.

65. Should any dispute arise between the Engineer and contractor as to the true meaning of the drawings or specifications in any point, the decision of the former shall be final and conclusive.

66. And the said..., contractor, hereby expressly binds himself to indemnify and save harmless the City of.. from all suits or actions of every name and description brought against the said City, for, or on account of, any injuries or damages received or sustained by any party or parties by or from the said...................

....

or his servants or agents, in the construction of said work, or by or in consequence of any negligence in guarding the same, or any improper materials used in its construction, or by or on account of any act or omission of the said..or his agents.

67. In consideration of the completion by said party of the second part, of all the work embraced in this contract, in conformity with the specifications and stipulations herein contained, and in strict accordance with the instructions of the Engineer, the City of......................

.................., party of the first part, hereby agrees to pay to the said

party of the second part, the prices named in the "PROPOSAL" which is hereto annexed, and which is hereby made a part of this contract.

68. Payments for the work shall be made monthly upon the estimate of the Engineer. ....per cent. ($\frac{}{100}$) of the amounts due will be retained as a guarantee against poor workmanship and materials. One-half of this reserve will be paid as soon as the work is completed and accepted, and the other half at the expiration of one year after the acceptance of the work.

In Witness Whereof,..

....

....

....

....

....

....L. S.

....L. S.

....L. S.

....L. S.

....L. S.

....L. S.

STATE OF.............................. }
..........................*County*. } ss.

On this.......day of................ ...., 188.., before me personally appeared..

....

....

....

....

....

....

Notary Public.

[Form of Bond.]

BOND.

Know all Men by these Presents, That we..........................

....

....

are held and firmly bound unto the City of................................,
in the sum of..Dollars,
lawful money of the United States of America, to be paid to the said
City of..................................., or to its certain attorney
or assigns, to which payment, well and truly to be made, we bind ourselves, our heirs, executors, and administrators, and each and every of them, firmly by these presents.

Signed and sealed with our seals, and dated at....................
.........................this.......day of...................., 188..

The Condition of this Obligation is such, That Whereas, the said......
....ha....
entered into a contract with the City of.................................,
bearing date the.......day of........................., 188.., which
said contract is hereunto attached.

Now, Therefore, If the said......................................
shall well and truly keep and perform all the terms and conditions of
said contract, on...............part to be kept and performed, and shall
indemnify and save harmless the said City of.........................
.................., as therein stipulated, then this obligation shall be of
no effect, but otherwise it shall remain in full force and virtue.

....L. S.

....L. S.

....L. S.

....L. S.

CHAPTER IX.

CONSTRUCTION.

Before staking out the line it will be necessary to find out the location of whatever gas, water, and sewer pipe may have been previously laid. This is not always easily accomplished. Work of this kind is frequently done under the direction of the so-called "practical man," who scorns "theory and science," and whose sublime confidence in his own ability is only equaled by his capacity for engineering blunders, as exhibited in bad plans and worse construction.

One of the most annoying things to be met with in locating sewers is to find water and gas pipes running haphazard through the streets, having been put down without system or sense, and, worse than all, to find that no map or record of their location has ever been made.

Importance of Record.—The value of the work will largely depend on the facility and accuracy with which the exact location, laterally and vertically, of every part of the system can be indicated; and hence in the construction notes such methods must be used as will be rapid, accurate in the greatest possible degree, and least liable to mistakes in recording.

The following described methods have been found to give good results:

Alignment.—First, let the centre line of the sewer be located carefully on the ground with a transit, making a study, as the line is extended, of the map of gas, water, and sewer pipes previously referred to.

All measurements should be made with a steel tape, and all notes made to the centre line of the sewer as run. Since it would be impossible to preserve this line, however, during the construction, no stakes need be left in it, but stakes should be set to the right or left a uniform distance of about one foot greater than half the width of the proposed trench. This will

bring them within the space on the bank usually left clean for the workmen to pass and repass in handling material, etc. The position of stakes is shown in plate I.

The stakes should be set at uniform distances of twenty-five feet apart, or less. They should be about one inch square in section, square on top, and of such a length that they can be driven flush with the surface of the street. Where extreme accuracy is required it will be well to indicate the precise point in the stake by a tack driven into its top; but ordinarily, with the size of stake indicated, this will be unnecessary. The offset line should uniformly be taken on the same side to avoid confusion, and the notes should indicate the side on which it is taken.

Reference Points.—The line is best located by observing to the nearest tenth of a foot the station which is intersected by the prolonged lines of brick walls or other permanent lines

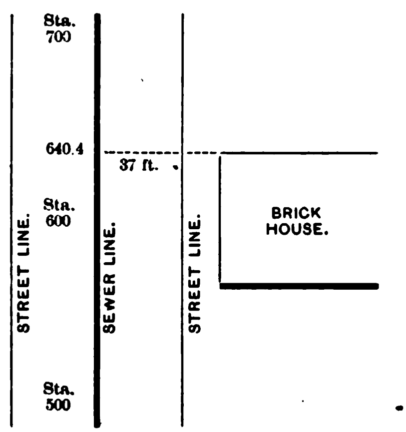


FIG. 3.

which are clearly defined, and also the distance from the corner of the building, the line of whose wall is prolonged, to the centre line of the sewer at the station observed as above. (See Fig. 3; the prolongation of the brick wall intersecting the true line at station 640.4, and being at this point 37 feet distant from the corner of the building.) This will be found a much more satisfactory location than the ordinary method of tie lines or focal co-ordinates, requiring less description in the notes, and giving a

sharper determination of the point. It may be supplemented at street intersections and changes in direction, however, by the latter method with advantage.

Methods of Work.—Two rules should be kept in mind in this method of location, viz.: Never record a measurement to the offset line, as it is only for use temporarily. Never leave a permanent stake in the true line, as it may lead to confusion.

There will be no difficulty in finding the offset stakes, even though they be driven flush with the surface of the ground, as, having a starting point, nearly the precise location can be determined by measurement. When the streets are paved with stone pavement, a block can be removed and the stake driven, and then the stone replaced. Ten miles of sewers were located in this manner in cobble-stone pavement in Schenectady, N. Y., and although nearly a year elapsed before their completion, no difficulty was found in locating the line.

At changes in direction, the angular deflection should be recorded, and also the location of the intersecting tangents, with reference to prominent and permanent objects.

Curves.—When the angular deflection is slight, no curve will be required in the original location on the ground, but the notes should give the offset to be made from the intersection of tangents and from short stations equally distant from it on either side. The exact location of the centre line can then be determined by drawing a tape on the tangents either way from the intersection of tangents, and measuring the offset required from the proper points on the tape, with an offset rod.

When the angular deflection is considerable, the curve should be run by transit or chord deflections in stations of twenty-five feet. Intermediate points can be interpolated in construction by ordinates from the chord.

The method above indicated, when faithfully pursued, will enable us to replace any point in the transit line with precision.

Transit Notes.—The transit notes should indicate approximately the distance from the sewer line to the buildings on either side, where they stand back from the street line. This may be taken by a good transit man with sufficient accuracy by the eye, aided by an occasional measurement.

The intersection of both lines of all crossing streets should be noted by station on the transit line, and also the offset from the transit line to angles in the street line. All crossings of streams should also be taken, and whatever notes are necessary to completely determine and indicate the physical characteristics of the territory.

The location should proceed from the outlet upward toward the higher levels of the system, and the various tributary branches should be tied to one another and to the main lines as often as possible, as a check on the work and as a guide in platting the finished map.

Level Notes.—The transit party should be followed by the leveler and assistants. The surface elevation should be taken on the true line, which can readily be obtained from the stakes left by the transit party by an offset measured by the leveling rod, or in ordinary cases can be determined with sufficient accuracy by the eye, after a little practice. The levels should be carefully checked at each bench-mark, as described on page 43. In cases where there is a sharp transverse slope to the surface of the ground, or when the buildings on one side of the street are considerably elevated or depressed below the street level, this should be carefully noted, and also the depth of basements, and any conditions, a knowledge of which will aid in giving a proper sewerage system to each building.

The level of all streams should be taken, and so far as it can be ascertained, the approximate level of the ground water. This can be ascertained with tolerable precision by observing the condition of wells bordering the street, when such can be found. The levels of water in these should be taken at intervals, and on both sides of the street, as the subterranean water surface may have a sharp decline in the direction of its natural drainage basin.

In cases where it is probable that the construction work will shortly follow the adoption of a plan, and where the physical character of the territory is sharply defined, and the drainage lines are apparent on a superficial inspection, the preliminary and final survey may be combined in one with economy.

Profiles.—The transit and level notes being complete, profiles of the several lines should be made to a large scale, showing the surface and grade lines, intersecting streams, etc. It will save the engineer much annoyance if the contractor be furnished a duplicate of the profile or a statement of the cuts at the several stations, as he can then intelligently plan his work from the outset without further questions. The ordinary profile paper, known to the trade as Plate A, will be found suitable for this work, and a convenient scale will be one foot vertically for each one-fourth inch, and one hundred feet horizontally for each two and one-half inches, to which the Plate is adapted. Cuts can be taken from this scale with tolerable accuracy, and they will serve as a check on those found by computation.

Working Map.—The plan being definitely decided upon, and the profiles made as described, a rough map should be made for use in construction, showing position and size of sewers, location of man-holes, lamp-holes, flush-tanks, and other accessories, and kept in the office for convenient reference during the progress of the work.

Note Books.—Each constructing engineer should be furnished with a field book, arranged something as follows:

LEFT HAND PAGE.				RIGHT HAND PAGE.
Station.	Surface.	Grade.	Cut.	Construction Notes.

The four columns at the left should be filled from the notes in the office, and the construction notes should be taken as the work proceeds.

Construction.—It is generally best to commence the construction at the outlet and work toward the higher levels. When this is done, the spigot of each pipe is easily inserted in the

socket of that already laid. There is also no tendency of the pipes to *crawl* away from the work or to open at the joints before the cement may be entirely set.

In some cases, however, where the grades are flat, and water is found in large quantities in the trench, the pipes can be laid from above downward with advantage, as the water can thus be drawn away from the pipe into the lower levels of the trench and then pumped out without interfering materially with the laying of the pipe. The pipe should be laid in each case with sockets up or toward the summits, and spigots down or toward the outlet; and when the work proceeds from above there is more difficulty in making proper joints and in inserting the gasket.

The pipe should be supported entirely on its cylindrical part, as shown in Plates I and VII, a recess being formed to receive the socket and the cement joint.

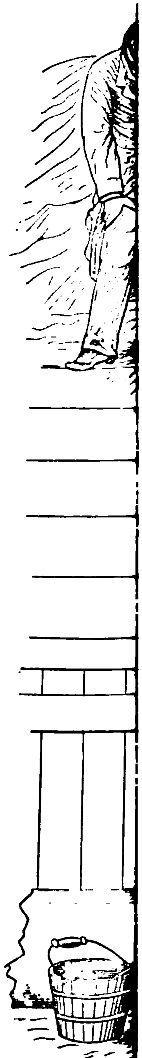
Pipe Laying.—The organization of the gang for work may be as follows:

The earth can be removed from the trenches to a depth of about the centre of the pipe by common laborers. The pipe laying gang should be preceded by men trained to the purpose, whose business it is to shape the trench for the pipe. In laying the smaller sizes, the pipe layer will need no helper in the trench, but can receive the pipe from his waiter on the bank, and place them unaided. In laying pipe of larger size, he should sit or stand astride of the pipes already laid, and his assistant should receive the pipes from above and assist in placing them. The gang is shown by sketch opposite.

The joints should be cemented by a person specially trained for the purpose. This can best be done by the hands encased in rubber mittens or gloves, and they should be wiped something as a plumber wipes a joint.

After the joints are cemented, the pipe should be carefully bedded, and all Y branches carefully packed and covered by a trusty man in advance of the regular back-filling gang.

When the depth of excavation is considerable, and the streets narrow, or the buildings close to the street line, Y branches should be more elevated than when opposite conditions are found.



Various mechanical devices have been proposed for ensuring the concentricity of the pipes. It is doubtful if they are of any great benefit, however. Pipes which are not truly formed should be rejected. Pipes which have too loosely fitting spigots and sockets should also be rejected, as any imperfection in form is less apparent and the axes of the pipes when laid are less likely to coincide. Since the flow rarely rises above the horizontal diameter of the sewer, particular care should be taken to have its invert as perfect as possible.

With good management on the part of the contractor, sewers of vitrified pipe of small diameter, laid in trenches of the depth usually necessary, can be laid much more rapidly than sewers of larger diameter, the rate of progress being limited in either case by the work of one gang of pipe layers or brick layers. Rapid and carefully systematized work by the constructing engineer is therefore required, who should take personal charge, as the decisions constantly needed in its progress, the locating and recording of junctions and similar work cannot be left to an inspector. A sufficient number of junctions should be inserted to meet all future demands. Connections by cutting into the pipes where no junctions are placed can be made with about the same facility as if the pipes were of plate glass, and if so made will ruin the sewers. A perfect record of everything pertaining to the work should be made for future reference.

Depth.—The depth to which sewers should be laid in the street will be determined by local conditions. In the closely built business portions of towns, however, where the ground floor space is valuable, property owners frequently desire to place water closets, urinals, laundries, etc., in the basement, and although this is not a desirable place for them it sometimes becomes necessary to adopt this course as the lesser of two evils.

Pipes should never be laid under basement floors when it can be avoided, but should enter the basement just above the floor and be supported by substantial iron brackets or hangers.

In cases where it is necessary to locate plumbing fixtures in basements the following will be a reasonable allowance for the depth of the sewer in the street:

Depth of basement below street level,...	9.00	feet.
Inclination of house sewer, 1-60 (50 feet),	.83	"
Diameter of street sewer (8 inches),......	.67	"

It will often be impossible to secure the desired depth. The problem then becomes to secure the maximum depth consistent with requisite grade, etc.

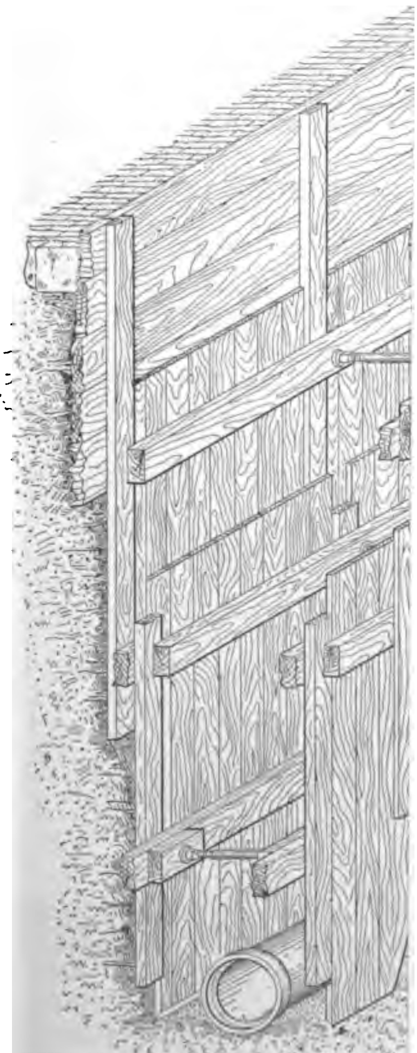
It is advisable in all cases to keep the sewers at least seven or eight feet below the street surface in northern towns, to avoid water and gas service pipes and mains.

There is little danger of sewers freezing, even though they be laid quite near the surface.

Grade Line.—The pipe should be laid to line and grade indicated by stakes driven in the bottom of the trench, the top of the stakes being to exact line and grade. These should be set in advance of the final shaping of the trench, in the following manner: The line is determined by laying an offset rod across the trench at the offset stakes, which were set in the final location, and setting the stake in line by a plumb-bob. The stake should be driven to grade by a relf-reading rod, read directly from the level whose elevation above the assumed datum should be carefully checked at each bench-mark. No setting of grade pegs by measurement of cuts from the surface should be allowed. A convenient and cheap rod is shown in Plate I. Sixteen feet will be found a convenient length.

Bracing and Sheet Piling.—In many soils it will be necessary to protect the sides of the trench from caving by timber and braces. A very good method of doing this is shown in detail in Plate IV. The iron screws will be found a great saving over the ordinary method of cutting timber shores, which, in many cases, can be used but once, and are liable at any time to become loosened. The iron screws can be used any number of times, will fit any width of trench within reasonable limits, can be quickly placed and removed, without jarring the trench, and can be tightened at any time, without the trouble and risk of removing a short one and inserting a longer one in its place. These screws can be manufactured at present prices for about $2.50 each. One hundred screws of assorted lengths make a fair outfit for one gang of pipe layers in ordinary work.

The method of bracing and sheet piling can be better understood from a study of the drawing than from a written description. It requires considerable experience to place it and remove it quickly and without damage to the material. By the use of



this method of bracing and sheet piling, the driest sand and gravel can be excavated cheaper than soil sufficiently tenacious to support itself, in trenches exceeding seven or eight feet deep, though the sides of the latter need no protection.

The drawing shows two rows of piling; these can be increased to three or four, or still more, if necessary. Up to a depth of eight or nine feet one row of piling, in connection with the horizontal planking, will be sufficient.

The following bill of material may be of service:

SINGLE ROW OF SHEET PILING.

This will be sufficient up to a depth of eight or nine feet.

Each section of sixteen feet in length requires the following material:

LUMBER.

10	pieces	2x10,	16	feet	long.	550 feet B. M.
36	"	1x10,	7	"	"	
4	"	2x 8,	7	"	"	
4	"	3x 6,	16	"	"	
4	"	3x 6,	1	"	"	

IRON SCREWS.

2	screws	36	inches	long	(closed).
2	"	30	"	"	
2	"	24	"	"	

The above bill requires a trench four feet in width at the top, and gives a clear space at the horizontal diameter of the pipe of forty inches, and between the horizontal timbers a clear space of thirty-four inches. This will be sufficient for a pipe eighteen inches in interior diameter. For larger sizes the length of the screws must be increased, and for smaller sizes the trench may be somewhat narrower.

DOUBLE ROW OF SHEET PILING.

This will be sufficient up to a depth of thirteen or fourteen feet.

Each section of sixteen feet in length requires:

LUMBER.

10	pieces	2x10,	16	feet	long.	829 feet B. M.
72	"	1x10,	7	"	"	
8	"	2x 8,	7	"	"	
8	"	3x 6,	16	"	"	
6	"	3x 6,	1	"	"	

IRON SCREWS.

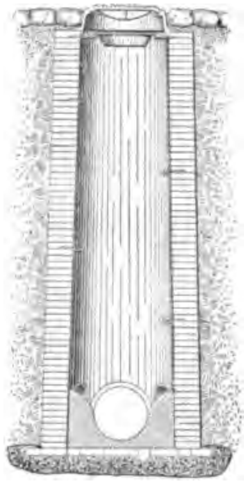
2	screws	36	inches	long	(closed)
1	"	30	"	"	
1	"	24	"	"	
2	"	20	"	"	
2	"	14	"	"	

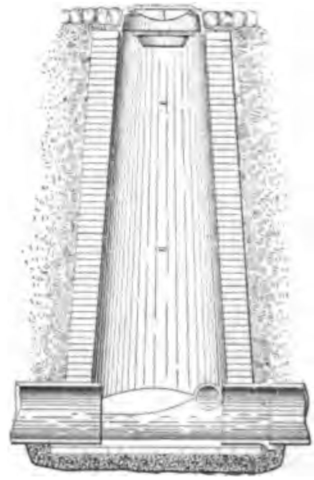
The above bill is figured for a trench four feet wide at the top, and gives a clear space at the horizontal diameter of the pipe of thirty inches, and a clear space between the lower horizontal timbers of twenty-four inches. This will be sufficient for pipes of twelve inches in diameter and less. For larger sizes the width of excavation should be increased.

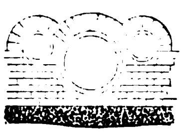
In heavy ground the length of the horizontal timbers may be reduced to fourteen feet or twelve feet with advantage, or an extra set of uprights may be used, dividing the sixteen foot sections into thirds instead of into halves.

Inspection of Material.—All sewer pipe should be inspected as fast as it is delivered at the work, and imperfect pipe should be plainly and indelibly marked and immediately removed. The engineer should also carefully scrutinize all pipes as they are passed to the pipe-layer, making sure that none which may have been broken since the formal inspection are

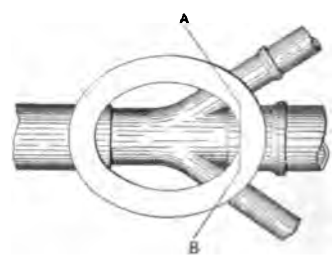
PLATE V.

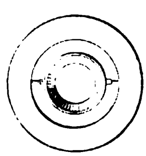


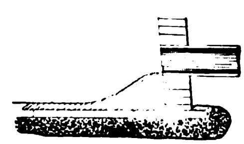




SECTION ON A B





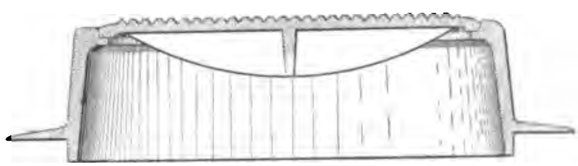


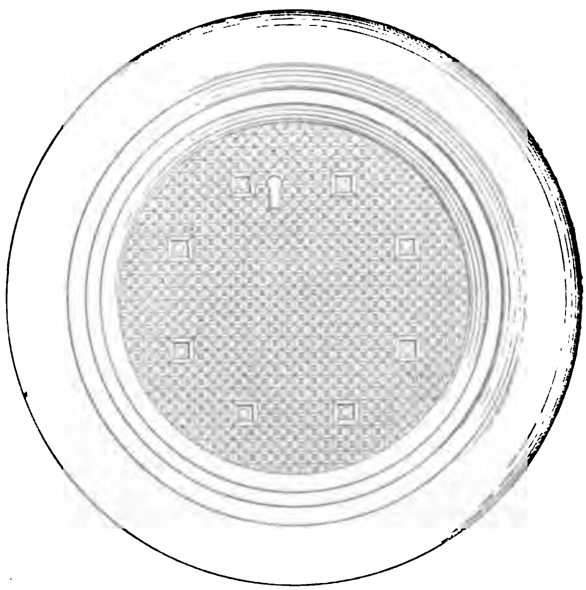
DETAILS

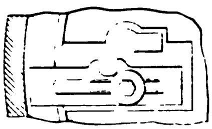
— OF —

MAN HOLE.

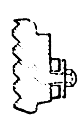
PLATE VI.







LOCK



IRON COVER,
MAN HOLE
— AND —
FLUSH TANK.

laid in the trench. The subsequent breaking or giving way of a single section of pipe may cause a great amount of damage.

All other material should be inspected by the engineer in a similar manner, and that which is unfit for use promptly removed.

Location of Y Branches.—Property owners should be consulted as to the position in which they wish their Y branches placed, and it would be well to send them somewhat in advance of the construction a printed notice. If no return is made by the property owner, the engineer should locate the junction as appears most convenient for the property.

The position of all Y branches should be located by station, specifying whether they are north or south, east or west. Any other location is unnecessary and confusing. The location is best made from the centre of the opening, as shown in Plate I. This should be taken to the nearest tenth of a foot, and a plumb-bob should be used to transfer the point to the surface.

Artificial Foundation.—When very treacherous quicksand is encountered it will be necessary to support the pipe on piles or blocks until the earth can be tamped around it. When soil of a less treacherous nature is encountered it may be sufficient to remove the soil somewhat below the grade line and replace with clean gravel.

Particular care should be taken to secure a firm foundation for man-holes, flush-tanks, and lamp-holes, as their greater weight may cause a settlement which will break the pipes.

Man-Holes.—Man-holes should be built with an eight-inch brick wall, as shown in Plate V. They should be plastered outside and inside. The iron cover with which they are surmounted should weigh from 300 to 500 pounds. The style shown in Plate VI has given good satisfaction when made to weigh 350 pounds. It has the following advantages: The least possible surface is exposed to traffic. The impact of passing wheels comes well within the base. The interior downward projecting rim prevents any loosened brick from falling into the sewer.

It is usual to hang a dust-pan below the perforations in the cover to catch the street detritus which may work through them. With good grades, however, there will be no danger of stoppage from this source when they are omitted.

The method of forming the bottom of man-holes to preserve the proper cross-sectional form of the flow is shown in section. The method of connecting a sewer of small diameter with a larger one is also shown. Unless particular care is taken in forming these curves, solid matters will be stranded in the man-holes and become offensive.

Iron steps may be built in the wall, or a light, portable ladder used in ascending and descending. The steps are most convenient, but are liable to collect street detritus falling from above.

Flush-Tanks —Flush-tanks should be built with an eight-inch brick wall, and plastered inside and outside with cement mortar. The upper courses of both man-holes and flush-tanks are exposed to the action of alternating frost and moisture in an unusual degree, and to the constant impact of vehicles, and with the best of material a four-inch wall is not sufficiently durable.

The interior of the flush-tank should be connected directly with the sewer, independently of its discharge, by a pipe of large diameter, as shown in Plate X. This will induce a current of air flowing along the crown of the sewer from the lower levels to pass into the tank and out through the perforations in its cover. No other protection against frost is needed. This is also a material aid in the ventilation of the sewers. All flush-tanks should be supplied with a dust-pan.

The various types of flush-tanks will be more fully discussed in the chapter on flushing and ventilation.

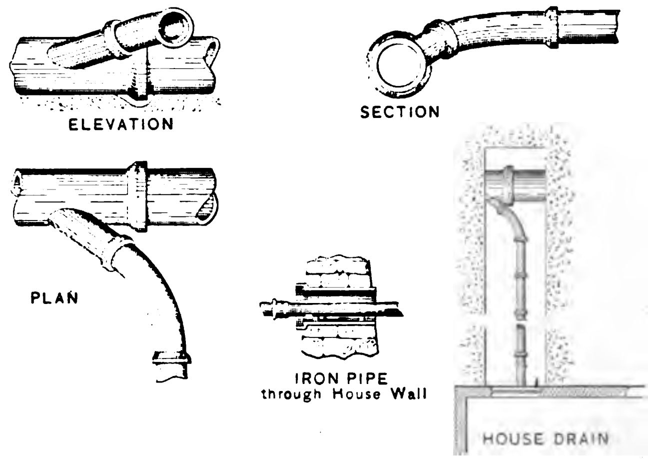
Lamp-Holes.—Lamp-holes should have a concrete bed under them to prevent settlement. They should be carried up as the trench is filled, and care must be taken to keep the sections vertical.

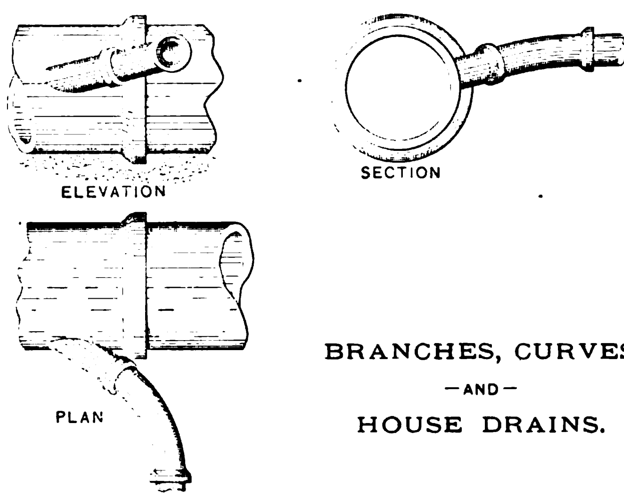
Care must be taken in locating man-holes, flush-tanks, and lamp-holes to avoid gutters, crossings, and other objectionable locations.

Upon leaving the work for the night, the ends of the pipe should be well cemented up as a protection against possible rain storms.

House Sewers.—Experience with sewers of the Separate System demonstrates that stoppages in the house sewers are much more frequent than in the laterals; and the point in the house

PLATE VII.





BRANCHES, CURVES
—AND—
HOUSE DRAINS.

sewers which are particularly liable to obstruction is at the junction with the street sewer. Particular care should, therefore, be taken in the construction at this point. The Y branch should be properly elevated so as to bring the invert of the house sewer above the ordinary flow line of the street sewer, as shown in Plate VII. The curve should have a sharp grade, and particular care should be taken to have the spigots put squarely into the sockets and the gasket well placed. No cutting and trimming of the pipe should be allowed, as it is impossible to make smooth joints of terra cotta pipe in this way. Curved pipe always warp unevenly in the kiln, and from an ordinary stock there will be no difficulty in selecting a curve suitable for any reasonable case. Three or four of these, slightly varying in radius, should always be at hand.

A very common defect is to allow the centre or belly of the curve to drop down and open the joints before they are hardened, or to do the refilling in such a manner that the subsequent settlement of the trench breaks the joints or pipe. This can be avoided by thoroughly ramming the earth up to the horizontal diameter of the curve as it is laid and water-tamping or ramming in layers above this.

House drains can be very nicely laid in favorable ground with an ordinary carpenter's level placed on each pipe as laid, one end of the level being supplied with a graduated slide and set-screw, by which is set off the fall corresponding to one length of pipe.

CHAPTER X.

FLUSHING AND VENTILATION.

Flushing.—To thoroughly flush a sewer requires a volume of water sufficient to fill the sewer for a considerable distance. The best results would be obtained if the sewer could for a time be filled its entire length, so as to flush all of the upper part of the pipe as well as the lower. This would not only cleanse the pipe, but materially aid in its ventilation by securing an entire change of air in the sewer.

If the sewers be designed to run half full of sewage during the hours of the greatest demand upon them, then sufficient water may be introduced to complete filling the pipes; that is, the amount of water for flushing may be equal to one-half of the capacity of the sewer. The difficulty of adjusting the amount of water for such complete flushing arises from the fact that the flow of sewage is not uniform. The maximum flow for a short time, under certain circumstances, may almost fill the pipe; now if arrangements are made to admit sufficient water to half fill the sewers at the time of maximum flow of sewage, the pipes will be surcharged and there will be danger of the sewage setting back into the houses.

When flush tanks are used to flush the sewers, if the discharge from the tank is sufficiently rapid, the flushing will be thorough, for a greater or less distance, depending upon the grade of the sewer. Gradually, however, the water will lose its velocity, and the flushing effect will be less and less until it amounts to but very little. Some means should be provided for giving at intervals a long continued flush. Especially is this the case where the fall is small and light grades a necessity, and where the effect of a flush-tank will be reduced to its minimum. This long-continued flush may be given in two ways; either by admitting roof water, or by arranging to connect the sewers with the water mains.

Roof Water.—When roof water is used for flushing, a difficulty arises in adjusting the amount of water to be admitted. When the sewers are first completed, much more water will be needed to flush them than will be required after their use has become general, and the flow of sewage has more nearly reached its maximum. But having once permitted the roof water from any building to be turned into the sewers, it is difficult to shut it out when the proper time comes; so that, to avoid trouble, no more roof water should be turned into the sewers at first than will always be needed.

If the sewers are designed to run one-half full of sewage during the hours of greatest flow, then the roof water introduced for flushing should be a little less than one-half of the capacity of the sewers.

When the sewers are flushed by connecting the dead ends of the sewers with the water mains, the amount of water can readily be adjusted to suit the requirements in each case. The water from the mains may be admitted to the sewers by a direct pipe connection, provided with a suitable valve; or it may be taken from a hydrant and carried through a hose to a lamp-hole at the dead end of the sewer, which in this case should be constructed as shown in Plate I.

Automatic Flush-Tanks.—Flush-tanks are used either to collect the sewage and discharge it rapidly at intervals for the purpose of flushing the sewers, or to collect and discharge clean water for the same purpose. They should be automatic in their action.

This regular and automatic flushing is peculiar to the Separate System, and the diminished size of the pipes renders it very effective. It sweeps down all deposits and stranded matter from the remotest portion of the system into the mains, and the aggregate of these discharges in the mains from tanks differently timed sweeps it on to the outlet. The more regular flow and consequent immunity from variations in air space and pressure reduce the danger of forcing traps. The smaller air space increases the efficiency of all openings in relieving any pressure resulting from such variations, and also increases their efficiency as ventilators.

There are many forms of automatic flush-tanks, most of

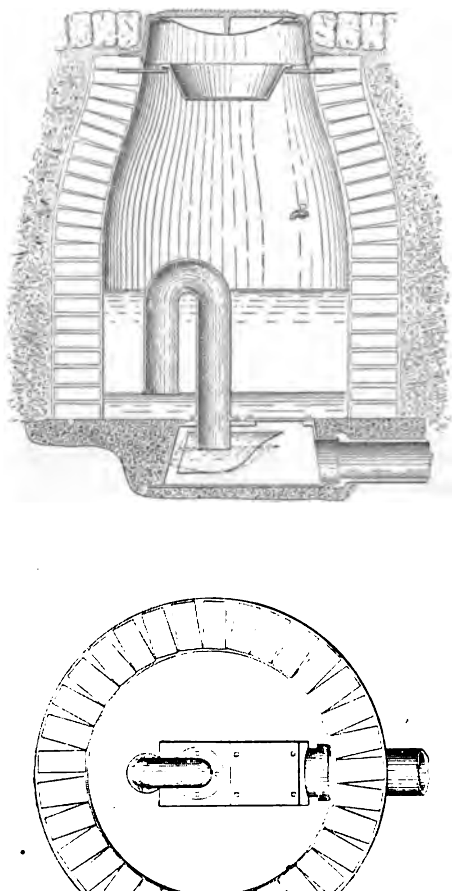
which may be classed under the four following varieties: 1, Tilting Tanks; 2, Syphon Tanks; 3, Valve Tanks; 4, Collapsers.

Tilting tanks are so designed that as they fill the centre of gravity is changed, until finally the equilibrium of the tank is destroyed, and the tank tilts over and empties itself. The tank is so adjusted that when empty it returns to its proper position. A tilting tank on a small scale is shown attached to the long leg of the syphon in Van Vranken's flush-tank, Plate VIII.

Syphon tanks are discharged by means of a syphon. They differ in the devices for starting the syphon. In places where the sudden rush of a considerable quantity of water can be secured, no device is necessary. Where house sewage is collected in tanks for flushing, the rush of water caused by emptying a bath tub, wash tub, etc., will be sufficient to start the syphon. But where the tank is filled by a stream of water small enough to fill a tank holding from one to two hundred gallons only once in twenty-four hours, some special arrangement will be necessary to start the syphon. This can be done by means of a small tilting tank on the long leg of the syphon, as in Van Vranken's tank; by a supplementary tank and syphon, as in Field's; by a ball cock, increasing the flow when the tank is nearly full, as in Vibbard's; by having the long arm of the syphon movable, as in Landon's; by a collapsing disk or tube, as in Chaplin's; by an automatic valve on the long leg of the syphon; and in various other ways.

Van Vranken's Flush-Tank.—This tank consists of an ordinary syphon, to the longer or descending limb of which is applied a small tilting tank. The arrangement of the parts is shown in Plate VIII. The tilting tank is hung directly below the descending limb of the syphon, at such a level as to leave its mouth sealed at all times. The tilting basis is contained in a small cast iron chamber, built into the bottom of the flush-tank chamber proper. The action of the tank is as follows:

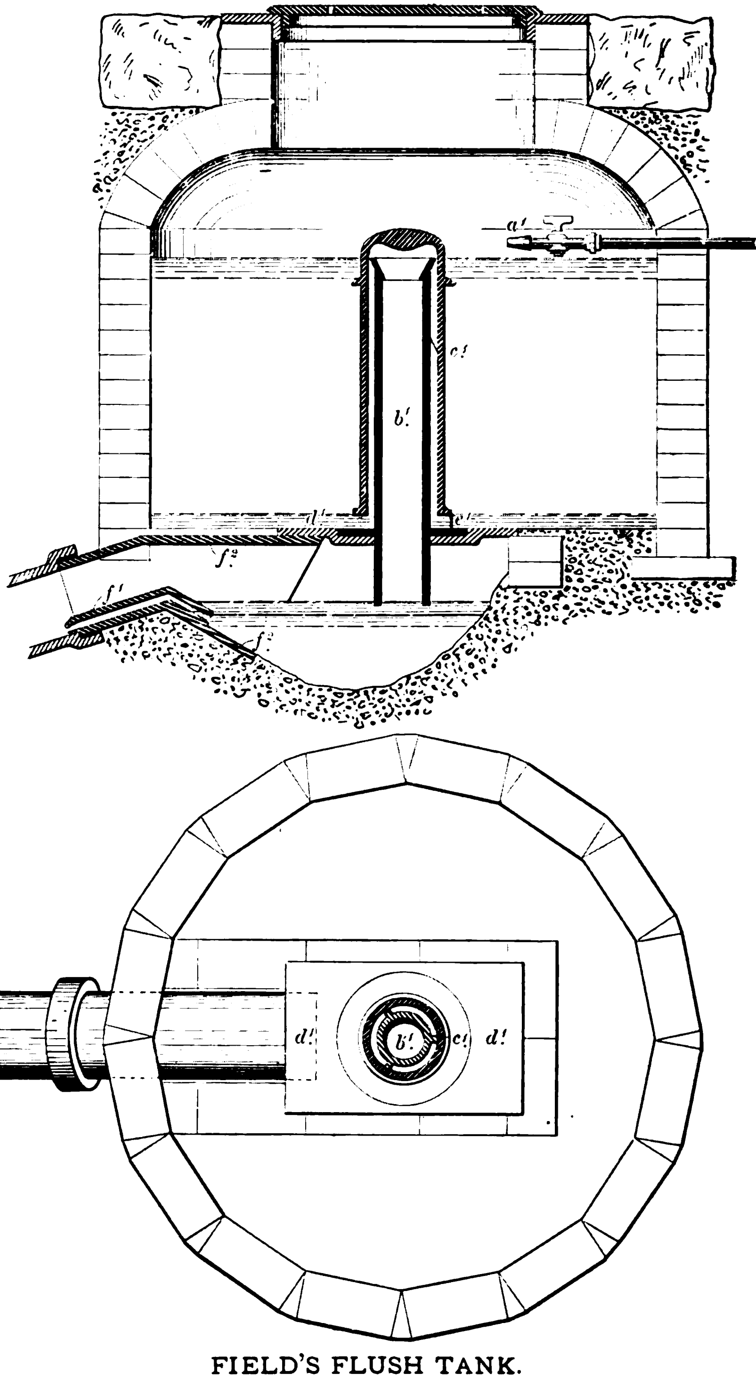
The water being admitted to the tank by an ordinary faucet, at whatever rate may be desired, gradually rises in the tank until it overflows from the ascending to the descending leg of the syphon and is collected in the tilting tank. As it accumulates in the tilting tank the centre of gravity is thrown beyond the axis of support and the pan tilts over, assuming the position



VAN VRANKEN'S
FLUSH TANK.

10

PLATE IX.



FIELD'S FLUSH TANK.

shown by the dotted lines, the water level in the basin being lowered about one inch. This produces a corresponding rarefaction in the syphon and brings it promptly into full action. When the tank ceases to discharge, the tilting basin resumes its former position. These tanks can be made with any size syphon desirable, and still will operate with the smallest supply of water possible.

Field's Flush-Tank.—This flush-tank is shown in Plate IX. It consists of the tank proper, provided with a supply pipe, by which a small quantity of water is constantly flowing into the tank. The syphon is annular in form, the shorter limb being formed by a cylinder closed at the upper end and held equidistant from the longer or descending branch by distance pieces. The lower end of the descending branch of the syphon should be sealed with water at the beginning of the discharge, and to insure the permanent cessation of its action when the tank becomes emptied the lower end of the descending branch should be unsealed. This is effected by the accessory syphon, which is brought into action by the rush of water into the lower chamber. The action of the accessory syphon continues until the water level in the lower chamber becomes lower than the mouth of the descending branch of the syphon, when the admission of air restores the normal pressure of the atmosphere.

Valve Tanks.—In the valve tanks some mechanism is employed to operate the valve, through which the water for flushing is discharged into the sewer.

Pierson's tank may be taken as an example of this class. It is shown in Plate X. It consists of a simple lift valve, opening outward, or in the direction of pressure, and contained in a small chamber underneath the tank chamber proper. The valve is actuated by a float which releases it at a certain water level. The float also performs the office of a weight, returning the valve to its seat when the water ceases flowing from the tank. The application of the levers is such that a small weight closes the valve very tightly, and the stop is so adjusted by moving the bolt in the slot, shown in the drawing, that the valve rod is thrown past the centre and the valve is secure against any reasonable pressure.

Healy's tank has an improved valve, made oblong in form, so that it can be removed and repacked without removing the cover of the valve chamber.

Collapsing Tanks.—The collapser invented by W. S. Chaplin is shown in Plate XI. It consists of a collapsing tube, whose diameter is a little greater than that of the outlet in the bottom of the tank. The lower end of the tube is fastened to the outlet, and the upper end to an orifice in the bottom of an open-top pan-float. The tube is provided with rings, so that while it collapses readily in a vertical direction, it holds its form horizontally. As the tank fills, the pan-float rises until it is held down by the collapsing tube. The water, continuing to rise in the tank, finally runs over into the pan, which immediately drops to the bottom, and the water runs out through the orifice in the bottom of the pan and the collapsed tube.

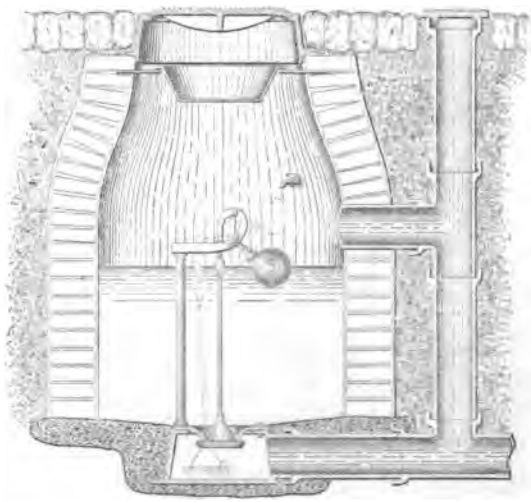
Requirements to be Met.—The requisites for an automatic flush-tank are: 1, Certainty of action; 2, Rapidity of discharge; 3, Simplicity of construction; 4, Ease of inspection of all of its parts; 5, Durability; 6, Economy of cost and maintenance.

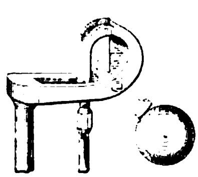
In a recent trial of flush-tanks in Schenectady, N. Y., the greater part of those experimented with failed in the first requirement—certainty of action. Inventors sometimes forget that the conditions required for operating a model may differ widely from those required when the design is made full size. A stream of water large enough to start a small syphon may have no effect on a larger one, similarly proportioned.

Strange as it may appear, there are flush-tank syphons, sold in considerable numbers, which can not possibly be made to work under the usual conditions imposed by the requirements for flushing sewers. After trying a syphon of this sort, under the direction of a man sent by the manufacturer, until it was perfectly sure that the device was a failure, the response from the agent to the assurance that the syphon would not work, was: "It must work; why! I have sold a large number, and have taken an order for several within a week."

The second point—rapidity of discharge—is next in importance to certainty of action. The sewer pipe should be filled for some distance in order to get the proper benefit from the flush.

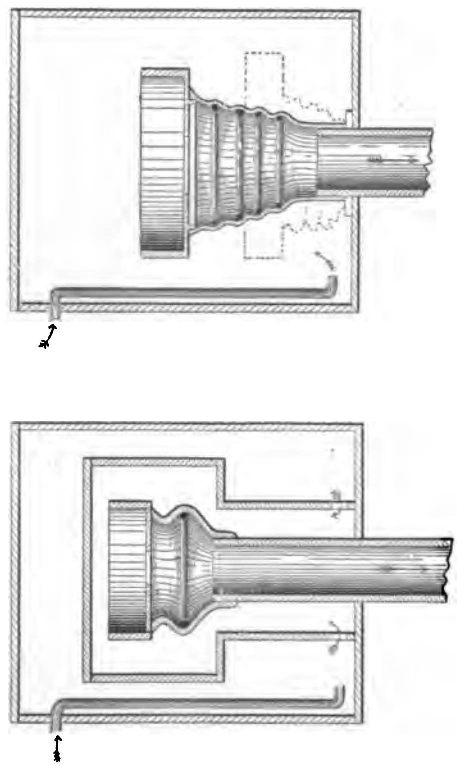
PLATE X.





PIERSON'S
FLUSH TANK.

PLATE XI.



Collapser Applied to Syphon.

COLLAPSING TANKS.

In this respect the valve tank has certain advantages. The valve may be made of almost any desired size, while the size of the syphon pipe is, with some of the devices for starting the flow, limited. In one well known tank the funnel in the syphon contracts the overflow to about three inches. It is evident that six or eight-inch sewer pipe cannot be effectively flushed with a three-inch stream.

In simplicity of construction the syphon tanks are superior to the valve tanks; and as durability is likely to depend upon simplicity of construction, the syphon tanks will, in general, be most durable.

Complicated mechanism is undesirable for use in a flush-tank, which must work automatically, and often for a long time without inspection. It is not at all uncommon to find that devices which look well on paper fail utterly when put to the test of actual service.

The results of the experiments with flush-tanks in Schenectady show that the Van Vranken tank is the best one yet devised. It is reliable in action; it discharges two hundred gallons in about thirty seconds; it is simple in construction; all its parts can be seen by simply removing the flush-tank cover; it is durable; and it is one of the least expensive tanks made.

Quantity of Water Required.—An erroneous idea prevails as to the quantity of water required for flushing sewers by the use of automatic flush-tanks. A properly designed system for a city of 10,000 inhabitants ordinarily requires from twenty to fifty flush-tanks, each of a capacity of about 150 gallons, discharging daily, or at most twice a day. The maximum amount of water required is about two per cent. of the water supply. This momentary discharge does not sensibly occupy the capacity of the main sewers further down the line, being, as before stated, but a very small percentage of the ultimate discharge. An equally efficient flushing by a constant stream, applied directly and without the intervention of a flush-tank, would require an amount of water materially encroaching upon the capacity of the main sewers, and would be inadmissible under ordinary conditions of water supply, on the score of economy.

Rapidity of Discharge.—Flush-tanks are ordinarily constructed of about 125 gallons capacity, and adjusted to discharge

automatically once or twice in each twenty-four hours. Their capacity of discharge should equal that of the pipe into which they empty.

Experiments made by the writer with a flush-tank of 7,000 gallons capacity, having a ten-inch outlet, opening into an eight-inch sewer, demonstrated that with the minimum grades indicated in Table XII, there was no danger of gorging the sewer at a distance of one or two hundred feet from the flush-tank, although the hydraulic head was seven feet. At a distance of 600 feet the flow, as observed in a man-hole, did not fill the sewer.

In the case of flush-tanks as ordinarily constructed—say 125 gallons capacity, three feet hydraulic head, tributary to a six-inch sewer—the tank can hardly discharge too rapidly.

The rate of discharge from the tank should at least equal the capacity of the sewer when the flow has acquired the velocity due to its inclination. A sewer six inches in diameter, laid at a grade of five-tenths per hundred, discharges, when full, at the rate of 215 gallons per minute. The conditions above named would therefore require the 125 gallons to be discharged in thirty-five seconds.

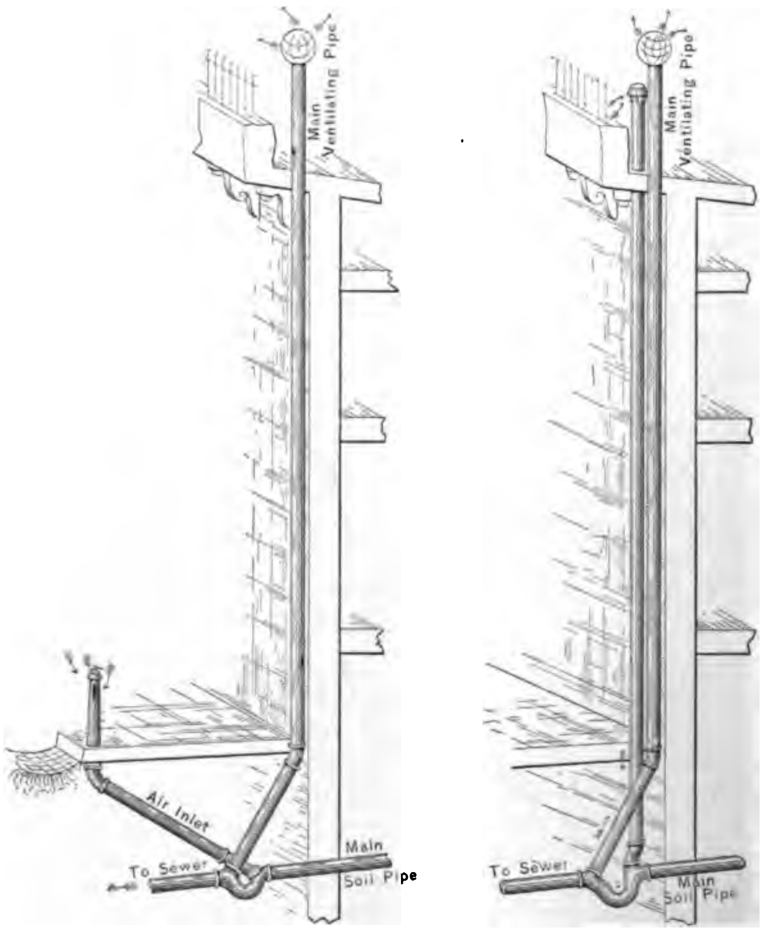
In the case of the large tank above given, the contents of the tank would be contained in 2,682 feet of the sewer, while in the ordinary case cited the contents of the tank would be contained in eighty-five feet of the sewer.

Ventilation.—The man-holes, flush-tanks, and lamp-holes, when provided with perforated covers, as shown in the plates, will afford sufficient ventilation for the street sewers of the Separate System. The house drains, however, need some special arrangement for that purpose. An opening from the house drain to the air is necessary, not only for ventilation, but to prevent emptying the traps by syphoning when the sewer is flushed.

The house drain can be ventilated by constructing on it at suitable intervals lamp-holes with perforated covers, as shown for the street sewer, or by a pipe carried up above the surface and topped with a half bend. It can, however, be done much more efficiently by carrying a ventilating pipe up above the roof of the house.

This may be done in two ways. The ventilating pipe may be carried up either on the inside or on the outside of the house.

PLATE XII.



MAIN VENTILATING PIPES AND TRAP.

When the main house drain is untrapped, and is carried up above the roof, it becomes an efficient ventilator, both for the drain itself and for the sewer, and no further ventilating device is necessary.

When the house drain is trapped, a separate ventilating pipe will be necessary.

If we could be perfectly certain that all of the drain, waste, and soil pipes were perfectly gas tight throughout their whole length, and would remain so; and that no fixture traps would ever be emptied by syphoning, evaporation, capillary attraction, or any other of the many ways by which traps *do* get emptied; we might safely use untrapped house drains. But taking the conditions as they are, it seems to be taking too great a risk to ventilate the public and private sewers *through* the dwellings.

S. Stevens Hellyer, the well known sanitary engineer, writes as follows:

"Where the drains (house drains) are carried direct into the sewer, without traps, the houses, through the sewer, are brought into direct communication with each other, *i. e.*, the air in the drain of one house can pass into the drain of another house. Contagious diseases—typhoid or what not—may be infecting a house, and however isolated it may be from other houses above ground, it would not be so *under* ground with such a system. The untrapped drains branching into the sewer would form a subterraneous passage for the bad air or disease germs—coming from the stools of the infected patients—between house and house. But when each house drain is trapped off before entering the sewer, an all but impassable barrier would be placed between the drains, so that the houses would be as much isolated under as above ground."

The two methods are shown in Plates XII and XIII.

CHAPTER XI.

HOUSE DRAINAGE AND PLUMBING.

House Connections.—In order to protect the sewers from injury by careless or incompetent workmen, or from stoppage by the introduction of improper substances into the sewers, proper rules and regulations for house drains and connections are necessary.

To permit each householder to connect with the sewers whatever he chooses, wherever he chooses, and in whatever way he chooses, is to insure ruin to the whole system. The house drains should be connected only at the Y's, which have been placed in position when constructing the sewers.

All work should be done by competent workmen, who are under bonds to do the work properly and repair all damage they may do, and under the direction of a trustworthy engineer.

Care must be taken to exclude everything which will be liable to obstruct the sewers. The man who said that he thought "the sewers should carry potato peelings and such things" is not alone in his notions regarding the disposal of garbage. A large majority of the domestics employed in families have unlimited faith in the capacity of waste pipes and sewers to carry empty cans, broken bottles, ashes, cinders, wash cloths, etc. This confidence in the carrying power of a pipe is so firm that it will be found easier to render the introduction of miscellaneous articles impossible than to demonstrate that the transportation qualities of a sewer are limited. It will be much better to prevent improper things being introduced into the sewers than to be obliged to dig up the pipes to remove obstructions. The sewers are intended to carry only fluid refuse from kitchens, laundries, water closets, bath tubs, slop sinks, etc., and care must be taken to exclude all solids, cloths, mud, and anything which would be liable to obstruct the flow in the pipes.

The house drains will be much more likely to get into bad condition than the public sewers, and hence the necessity for

great care in laying the drain and in providing for its ventilation and flushing.

Municipal Control.—It will be found best to pass a general ordinance, governing the use of the sewers by private individuals, and to leave matters of detail to be determined by the proper committee, so that changes in plans and specifications which may be found necessary can be made without the delay and trouble which often attend even much needed municipal legislation. The following are forms for the necessary ordinance, regulations, specifications, plumber's license, plumber's bond, owner's application card, and application and permit for permanent record.

The owner's application card is for the use of non-resident owners, and to save owners the trouble of going personally to the engineer's office. The regular application and permit is made out in duplicate, and one set is retained for record.

ORDINANCE.

AN ORDINANCE FIXING AND REGULATING THE USE OF SEWERS BY PRIVATE INDIVIDUALS IN THE CITY OF..............................

The Common Council of the City of....................do Ordain as follows:

SECTION 1. All connections of private drains or sewers with the public sewers of the City of..................shall be made in accordance with the plans and specifications approved by the Committee on Sewers, and on file in their office.

SEC. 2. No person or corporation shall make any connection with, or any opening into, any public sewer unless regularly licensed by the Committee on Sewers.

SEC. 3. Applications for licenses shall be made in writing to the Committee on Sewers on blanks provided by the Committee.

SEC. 4. Every person or corporation to whom a license is granted shall, at the time of receiving the license, file a bond, approved by the Committee on Sewers, in the sum of..........................Dollars—conditioned to indemnify and save harmless the City of..................from all damages arising from making connections with the public sewers.

SEC. 5. No person or corporation shall make any connection with, or opening into, any part of the public sewers without the written permit of the Committee on Sewers.

SEC. 6. Applications for permits to connect with the sewers must be made in writing by the owner of the property to be drained, or his

authorized agent. Such application shall give the precise location of the property, the name of the owner, and the name of the person employed to do the work, and shall be made on the day previous to opening the street.

SEC. 7. All permits to connect with the sewers shall be given upon the express conditions that the Committee on Sewers may at any time before the work is completed revoke and annul the same, and no party interested shall have a right to claim damages in consequence of such permit being revoked or annulled.

SEC. 8. The licensed plumber who connects any private drain with the public sewers shall be held responsible for any injury he may cause to the sewers or the public street. He shall restore the street to the satisfaction of the Superintendent of Streets, and make good any settlement of the ground or pavement.

SEC. 9. No person or corporation shall connect any open gutter, cesspool, privy vault, or cistern with any public sewer, or with any private sewer connecting with the public sewers.

SEC. 10. No rain-water conductors shall be connected with the public sewers, or with any private sewer connected with the public sewers, except for the purpose of flushing the sewer, in which case a special permit will be granted by the Inspector of the Sewers.

SEC. 11. No person or corporation shall injure, break, or remove any portion of any man-hole, lamp-hole, flush-tank, or any part of the public sewers, and when any person or corporation shall desire to lay or drive any pipe in any of the streets upon which sewers are laid, they shall give at least twenty-four hours notice to the Inspector appointed under Section 15 of this ordinance.

SEC. 12. No person or corporation shall deposit any garbage, offal, dead animals, filth, or any substance having a tendency to obstruct the flow of the sewage, in any man-hole, lamp-hole, flush-tank, or sewer opening.

SEC. 13. Any person or corporation offending against either of Sections 2, 5, 9, 10, 11 or 12 of this ordinance shall be subject to a penalty of not less than .... nor more than .... for each and every offense.

SEC. 14. The Sewer Committee shall have power to stop and prevent from discharging into the public sewers any private drain through which substances are discharged which are liable to injure the sewers or to obstruct the flow of the sewage.

SEC. 15. The Common Council shall have power to appoint an Inspector to whom they may delegate any or all of the powers herein conferred.

SEC. 16. This ordinance shall take effect immediately.

SPECIFICATIONS.

In accordance with the provisions of the foregoing ordinance, the Committee on Sewers have adopted the following specifications:

Specifications for Private Sewers Connecting with the Public Sewers.

1. The trench shall be dug so as to meet the public sewer, as shown in the drawings connected herewith.

2. The earth thrown from the trench shall be placed so as not to obstruct the gutter, and so as to cause the least inconvenience to the public.

3. Whenever the sides of the trench will not stand vertical, sheeting and braces shall be used to prevent unnecessary caving.

4. Proper barriers and danger signals must be maintained on the banks of the trench to guard the public against accidents during the progress of the work.

5. The house drains shall be salt-glazed, vitrified, earthenware pipes, of best quality, four inches in diameter.

6. The pipe shall be laid on an even grade of not less than one in forty-eight, unless provision is made for regular and efficient flushing.

7. Curved pipe shall be used for every deflection from a straight line.

8. The joints shall be made with a proper oakum gasket and pure cement of best quality.

9. The cover of the Y branch on the sewer shall be carefully removed so as not to injure the socket.

10. The first length of the pipe attached to the sewer shall be curved, and set as shown in the drawing.

11. The end of all private sewers, not immediately connected with the plumbing fixtures, shall be securely guarded by water-tight, imperishable material.

12. In back-filling, the earth shall be carefully rammed, so as to keep the pipe in proper position and avoid settling.

13. All of the material and workmanship shall be of the best quality, and subject to the approval of the Inspector of Sewers.

14. All private sewers connecting with packing houses, butcher shops, lard rendering establishments, hotels, restaurants, boarding houses, and laundries, shall be provided with a suitable grease trap.

15. All fixtures connected with private sewers, leading to the public sewers, shall be provided with suitable traps and strainers to prevent the introduction of improper substances into the sewers.

16. Nothing shall be connected with the private sewers, connecting with the public sewers, without the consent of the Sewer Committee, or their duly authorized agent.

The drawings referred to in the specifications are shown in Plates VII, XII and XIII.

PLUMBER'S LICENSE.

CITY OF.............................., SEWER DEPARTMENT.

No......... ....188.

....hereby licensed to do plumbing and lay house sewers in connection with the public sewers in this city in accordance with the provisions of an "Ordinance No........, fixing and regulating the use of sewers by private individuals in the City of................ ...."

....

Sewer.............. ....

PLUMBER'S BOND.

Know all Men by these Presents, that we,............... ...., of the City of......................, as principal, and......................... and........................., as sureties, are held and firmly bound unto the City of......................in the penal sum of.................Dollars, to be paid to the said, the City of.........................., or to its certain attorney, successors or assigns.

For which Payment well and truly to be made, we bind ourselves and our heirs, executors and administrators, jointly and severally, firmly by these presents.

Sealed this..............day of......................in the year of our Lord one thousand eight hundred and eighty-................

Whereas, The said party of the first part has made application to be licensed to engage in the business of connecting private sewers with the public sewers of said city, which license has been granted, conditioned upon the execution of this bond, as provided by Ordinance No.... of the Common Council of said city, passed......................

Now, therefore, the Condition of this Obligation is such, That if the said party of the first part shall well and faithfully, and in a workmanlike manner, perform the work of connecting such sewers, and shall save and

indemnify the party of the second part of and from all costs, damages and expenses arising from making such connections, or the negligence or carelessness of the party of the first part, his agents, servants, or employees, in making the same, then this obligation to be void, otherwise to remain in full force and virtue.

Sealed and delivered in the presence of

....

....

....

OWNER'S APPLICATION.

To the Committee on Sewers,............ ....

Please deliver to........................permit for a four-inch connection with the...........Sewer on.......................Street, for premises No....... ....Street. I authorize him to sign for me such an application for the same as is required by the regulations of said Department.

...................Owner.

..............................188..

APPLICATION FOR PLUMBING.

To the Committee on Sewers,....................................

No......... ....188..

The undersigned applies for permission to connect premises No...... .. ..Street, with the public sewer in................ Street, and to do the necessary plumbing, and I hereby desire a permit to be issued to...................... ...., a regularly authorized and licensed Plumber, to construct such sewer.

I hereby stipulate and agree that the work on said sewer shall be executed in strict conformity with the provisions of "An ordinance fixing and regulating the use of Sewers by private individuals in the........... ....," and the plans and specifications approved by the Committee on Sewers, and now in force in................... And the undersigned further agrees that all claims against the City of.... .... for damages occasioned in any manner by the putting in of said sewer shall be waived, and held null and void.

......................Owner.

PERMIT TO CONSTRUCT SEWER.

No.......... ....188..

Authority is hereby given to....................................
..................to execute the work for..........................
upon the terms and conditions specified in above application.

....

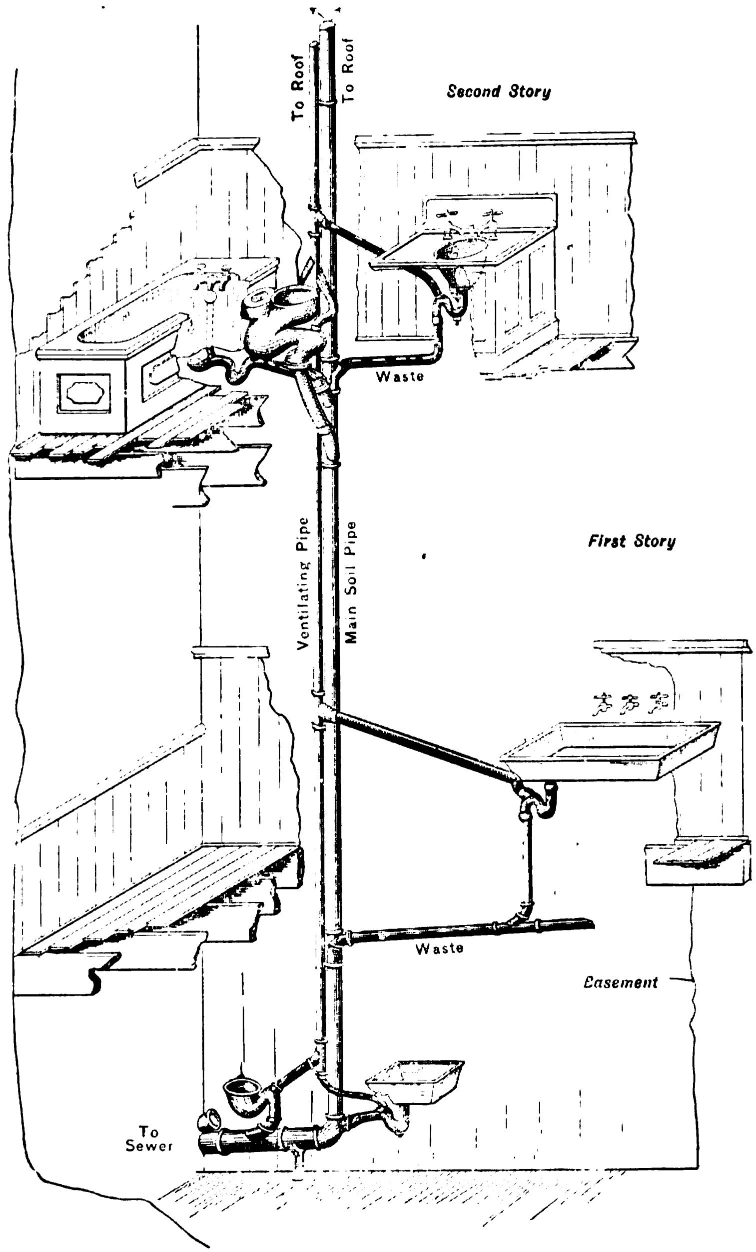
....

House Drains.—One of the most common blunders in house drainage is in making the drain too large. It is very rare that any house will require a house drain (i. e. the pipe which carries the sewage from the house to the public sewers) more than four inches in diameter, and yet it is not uncommon to find a private house provided with a drain large enough to carry the sewage of a town of five thousand inhabitants. This use of unnecessarily large pipe arises from two causes: The ignorance of the owner, who, not knowing what is required, determines "to have it big enough, any way," and the cupidity of the plumber, who favors any plan which swells the amount of his bill. Any unnecessary addition to the size of a house drain not only causes needless expense, but renders it more difficult to flush the drain and keep it clean. This point has been fully discussed in Chapter VI.

The practice of placing the house drain beneath the cellar floor is very objectionable for two reasons: It is out of sight and cannot easily be inspected, and it is usually laid on too flat a grade, especially when it runs beneath the floor for a considerable distance. The pipe should be placed along the cellar wall, or hung from the floor beams, so that it can be readily inspected, and can be given a proper grade to secure a sufficiently rapid flow of the sewage. T branches, with tight covers, placed along the pipe, will afford the means of inspecting the interior of the drain and removing obstructions.

The house drain within the house should never be of earthenware. It should be of iron, and heavy enough to admit of having the lead joints caulked so as to be water and gas tight.

PLATE XIII.



INTERIOR PLUMBING.

In order to provide for ventilating the house drain, it should be carried of full size up through the roof. To prevent the introduction of foreign substances into the top of the pipe, it is frequently provided with a half bend on top so as to bring the open end down, but the ventilation would be better if the pipe were left without a bend, and the top protected with a wire screen, as shown in Plate XII.

Grease Traps.—The principal danger of stoppages in a house drain, properly laid, arises from the grease carried into it from the kitchen sink. This can be avoided by the use of a "grease trap," placed under the sink. The objection to the use of a grease trap is that they need to be cleaned occasionally, and if not cleaned they get very foul.

Soil and Waste Pipes.—Soil pipes, that is, pipes leading from water closets; and waste pipes, that is, pipes leading from bath tubs, wash stands, etc.; may be either of iron or lead. Iron is the better material where it can be used, but lead is easier to fit and adjust where the connection between the fixture and the main drain is not direct. All iron pipes should be either enameled or coated inside and out with coal pitch varnish to give them a smooth surface and keep them from rusting. All junctions and changes in the direction of the pipe should be made by easy curves.

Traps.—The main house drain should be trapped between the house and the street sewer, and each fixture—water closet, bath tub, wash bowl, sink, etc.—should be trapped, separately, as close to the fixture as possible, as shown in Plate XIII. The fixture traps which are liable to be syphoned by the flow of neighboring pipes should be provided with vent pipes. A fresh air pipe, leading from the open air, should be joined to the main house drain on the house side of the main trap, as shown in Plate XII, so that there shall be a free passage of air from the outside of the house up through the main pipe above the roof. The pipe in the house being heated will cause an upward draught through the pipe.

Flushing.—An automatic flushing tank, holding about twenty gallons, and adjusted so as to flush the drain pipes once or more every day, should be placed above the highest fixture in

the house. By thus providing for thoroughly cleansing and ventilating the pipes, the danger from sewer gas is reduced to a minimum.

General Features.—Corners and recesses within the pipes and plumbing fixtures should be avoided. All interior surfaces should be thoroughly flushed at every rush of water through the pipes; otherwise the animal matter left sticking to the surface will decompose and send off foul gases. On this account the use of "pan closets," and many patterns of traps, should be discontinued. The plumbing fixtures in a house should be as few as possible. Not only is every additional fixture and pipe joint a possible source of danger, but the principal danger from sewer gas arises from rarely used fixtures, from which the water in the traps has evaporated.

The fixtures on the different floors should be arranged so as to have them as nearly in a vertical line as possible, in order to avoid running waste and soil pipes horizontally or with insufficient fall.

The less wood work around fixtures the better. Not only does the wood itself become foul, but the space within the casing is dark, damp, and dirty—a favorable locality for mould and rot. and a breeding place for vermin.

The common practice of placing water closets and other plumbing fixtures in dark, ill-ventilated places, such as inside rooms, dark closets, under stairways, etc., is wrong in every way. All plumbing fixtures and pipes should, as far as possible, be kept open to the air and light. The places which are naturally the most foul, stand most in need of sun light and pure air.

Where it is possible to avoid it, no plumbing fixtures should be placed in a bedroom. During the night some decomposition will be going on above the trap in any fixture, and some foul gas will be given off. This, with the chance of sewer gas coming in through some defective joint, pipe, or trap, makes the risk too great to be taken if it can be avoided.

Everything connected with house drainage and plumbing should be of the best material and most thorough workmanship. The best plumbing is not too good. By best plumbing is not meant the most showy, or necessarily the most expensive. Water closets and sinks are not the most appropriate places for gilt and

tinsel. On the other hand, it is poor economy to risk health and life on cheap, bad work in the sanitary arrangements in our homes.

Before accepting and approving of any plumbing work, it should be thoroughly tested, either by the water test or some other efficient method, to make sure that all of the work is water and gas tight.

RULES FOR HOUSE DRAINAGE AND PLUMBING.

1. The house drain shall be four inches in diameter, and laid on an even grade, of not less than one in forty-eight, unless provision is made for regular and efficient flushing.

2. The drain pipe from the public sewer to within three feet of the foundation wall of the house shall be of salt-glazed, vitrified, earthenware pipe, with joints made with a gasket, and pure, fresh ground hydraulic cement of best quality.

3. The drain pipe within the house, and extending three feet outside of the foundation walls, shall be of iron, and shall be carried of full size (four inches) up through the house and at least four feet above the roof, and left without bend or cap. The open top of the pipe shall be protected with a wire basket.

4. The joints of the iron pipes, except where screw joints are used, shall be made with an oakum gasket and soft lead thoroughly caulked.

5. The cast iron pipe shall be heavy enough to admit of caulking the lead joints so as to be water and gas tight without danger of breaking the pipe.

6. All iron pipe must be enameled, or covered, outside and in, with coal pitch varnish.

7. A four-inch running trap, with a hand-hole, fitted with a proper cover, shall be placed on the main drain just inside of the cellar wall.

8. A fresh air pipe, leading from the open air, shall be joined to the main house drain on the house side of the main trap, and no trap or other obstruction shall be placed in the main pipe between this point of junction and the open top above the roof.

9. If it be deemed necessary in any case to ventilate that portion of the house drain between the main trap and the public sewer, it shall be done by attaching a ventilating pipe to the house drain on the side of the main trap towards the public sewer. This ventilating pipe shall be carried up on the *outside* of the house to four feet above the roof. (Methods of arranging the ventilating pipes are shown in Plate XII.)

10. The drain pipe shall not be laid below the cellar floor, except it be absolutely necessary. It should be fastened along the cellar wall, or hung from the floor timbers, and given a grade of at least one in forty-eight, and more if possible.

11. All changes in the direction of the drain shall be made with curved pipe, and all connections, with Y branches and bends.

12. Every sink, water closet, urinal, bath tub, wash tub, basin, safe, or other fixture shall be separately trapped as near the fixture as possible.

13. Waste pipes from safes, refrigerators, cistern overflows, and water tanks from which water is taken for drinking or cooking purposes, shall not be connected directly with any soil pipe, waste pipe, or drain, but must be discharged into an open sink or into the open air.

14. Every trap shall be separately ventilated and protected from syphonage by a proper vent pipe. These vent pipes should enter the main vertical pipe above the highest fixture, or be connected with a special ventilating pipe, leading above the roof. The vent pipes must always have a continuous slope to prevent retaining the water which may condense in the pipes. (The proper arrangement of vent pipes is shown in Plate XIII.)

15. All exit pipes from plumbing fixtures, except the soil pipes of water closets, shall be provided with strong, metallic strainers, securely fastened.

16. All connections of lead pipes shall be made with wiped lead joints.

17. All connections of lead with iron pipe shall be made with a brass sleeve or ferrule, the sleeve to be thoroughly caulked into the iron pipe with lead, and the lead pipe to be attached to the sleeve by a wiped joint.

18. Water closets shall not be flushed by direct service, but by means of a special tank.

19. The vent pipes from water closet traps shall be at least two inches in diameter, and for all other fixtures, one and one-half inches. If the length of a vent pipe be more than twenty feet, the size of the pipe must be increased.

20. Arrange all pipes so that they may be easily examined and repaired. Where they are necessarily carried within the walls or partitions, cover them with wood work, fastened with screws, so as to give ready access to the pipes.

21. All materials shall be of good quality, free from defects and imperfections, and the work shall be done in a thorough and workmanlike manner, and subject to the inspection of the Inspector of Plumbing.

CHAPTER XII.

COST AND ASSESSMENTS.

Comparative Cost of the Separate and Combined Systems.—No *general* comparison of the economy of the Separate and Combined Systems of Sewerage can be made. It depends in all cases on the condition of each problem; and the relative economy in a particular case can be determined only by a competent engineer, after thoroughly considering the requirements to be met.

As indicated in a previous chapter, there can be no question as to which system will secure the most perfect and sanitary house drainage, whatever the conditions may be. In the Separate System proper, we are seeking this with a single aim, and may adopt anything conducive to it, and reject anything detrimental to it. How far we may depart from this line, from considerations of apparent economy, is a serious question.

It must not be forgotten that we are establishing a complete system of subterranean communication between the dwellings of all classes of society, interposing but a small volume of water as a barrier to the circulation of air currents; and when street water is admitted we are introducing another element of danger.

In many of the smaller cities in the United States (and they are comparatively numerous, as shown in Table I) there can be no question as to the superior advantages of the Separate System, in economy, efficiency, and adaptability to all the requirements to be met. In cities of this class it is folly to construct a Combined System, ill-adapted to the work in hand. The question of relative cost, though favoring the Separate System, is, therefore, not a pertinent one.

A comparison as to cost can only be properly drawn in the case of cities where considerable areas are paved and the storm water from them cannot be carried to the nearest stream without accumulating in the gutters to a degree interfering with business or threatening damage to property.

The admission of storm water to small streams traversing a city is entirely proper, and generally beneficial. Any filth brought from foul pavements is thoroughly removed by the afterflow of the rain which brings it, and also the filth accumulated in the bed of the streams during low stages of water, which is so potent a factor in pollution, and the accumulation of which, despite the stringent ordinances in force in cities of this class against the pollution of streams, it seems well nigh impossible to prevent.

Even in the Combined System it is usual to provide overflows for the escape of a portion of the storm water into the natural drainage channels.

"No system of sewerage yet proposed in any city contemplates the removal of *excessive* storm water by means of sewers alone,—such storms, for instance, as discharge for short intervals two or three inches of rain in an hour. These occur at long intervels, and are of short duration, and the damage is usually confined to limited areas; whilst the construction of sewers to meet the contingency would be attended with enormous expense over the whole city, both in construction and repair, and prove of doubtful efficiency when suddenly called upon, and extremely objectionable as conduits for the ordinary flow of sewage."—*Adams.*

In cities of this class, then, we may properly compare the cost of the Combined System uniting the house and manufacturing wastes with the storm water for removal in the same conduit, on one hand, with the cost of the Separate System proper, supplemented by conduits for the separate removal of surface water, where such are necessary, discharging into the nearest watercourse. Sewers for house drainage are required in every street or alley. Conduits for the removal of storm water from streets are required, with rare exceptions, only in alternate streets, extending from the natural drainage channels toward the crests.

It will thus be seen that even in very densely built portions of a city, if the sewage proper can be combined with the storm water without necessitating an extension of the large out-fall sewer, which otherwise would not be required, the sewers in alternate streets extending parallel with storm water conduits, and in every street intersecting them, may receive house drainage exclusively, to be finally discharged into the common out-fall.

In this case, if the city be laid out in regular squares, the Separate System will reach three-fourths of the dwellings without requiring a double system in any street.

It rarely happens, however, that such a combination can be made without requiring the construction of a long line of outfall sewer of large diameter, at a comparatively large cost, which, if the storm water was not combined with the sewage, might be of comparatively small size and cost.

In designing a system of sewerage, then, the vital question is not properly that of the comparative economy of the Separate and Combined Systems, but a question of the proper means to be adopted for doing the work required to be done.

Cost of the Separate System.—The principal items in the cost of sewers are: the pipe; trenching, laying pipe and refilling the trench; man-holes; flush-tanks; lamp-holes; and engineering and superintendence.

The pipe manufacturers issue price lists, and these, with the discount (depending upon the season, amount required, etc.), can be obtained by applying to the agents or general offices.

The only very uncertain item in the list is the second,—trenching, laying pipe and refilling. This will depend upon the nature of the soil in which the sewer is laid.

Quicksand is the most difficult material to manage. It will cost from two to five times as much to put in a sewer in quicksand as it will in ordinary earth.

Examples of Cost from Actual Work.—As a guide in estimating the cost of sewers of the Separate System, a few instances of the cost of actual work are here given.

In Table XVII will be found a statement of bids received on sewer construction.

The soil in which these sewers were proposed to be laid was, for the most part, favorable. It was necessary, however, to sheet pile the trenches nearly all the way. Very little hardpan was met in construction. About 1,500 feet of the Front Street main sewer was laid in quicksand, the water rising to an average depth in the trenches of about two and one-half feet. The cut under the New York Central Railroad, on Front Street, was peculiarly difficult; the depth of trench at this point being sixteen and one-half feet, the lower four feet of which was quicksand and water. More or less quicksand and water were encountered on all the streets leading from the lower levels of the town to the plateau on the east (see map in front of book), and also

TABLE XVII.

Bids on Sewer Construction, Schenectady, N. Y.

	Price per foot for excavation and back-filling under 6 feet.	Price per foot for excavation and back-filling over 6 feet and under 8 feet.	Price per foot for excavation and back-filling over 8 feet and under 10 feet.	Price per foot for excavation and back-filling over 10 feet and under 12 feet.	Price per foot for excavation and back-filling over 12 feet and under 14 feet.	Price per foot for excavation and back-filling over 14 feet and under 16 feet.	Price per lineal foot for furnishing and laying 8 inch pipe.	Price per lineal foot for furnishing and laying 10 inch pipe.	Price per lineal foot for furnishing and laying 12 inch pipe.	Price per lineal foot for furnishing and laying 18 inch pipe	Price per man-hole, including materials and labor.	Price per flush-tank, including materials and labor.	Price per lamp-hole, including materials and labor.	Price per lineal foot for repaving.	TOTAL ESTIMATED COST.
Estimated Quantities	33,700	10,000	5,600	2,500	700	300	39,590	3,780	5,710	3,720	25	25	100	40,000	
Samuel Moak	$ .16½	$ .22	$ 90	$ .93	$ .40	$ .45	$ .25	$ .34	$ .41	$ .60	$ 48 00	$ 47 00	$ 5 50	$ .08	$37,571.30
Hinds, Moffat & Co.	.21	.46	70	.96	1.12	1 82	.23	.31	.38	.65	42.02	72.25	8.20	.05	40,887.55
J. A. Hallnan	.27	.35	.80	1.00	1.50	3.30	.22	.30	.38	.82	51 00	76 00	10.00	.04½	42,658.00
Doyle & Stanton	37	.43	.54	.59	72	.90	.18	.27	.35	.52	38.00	40.00	2.25	.12	41,096.70
Robert Bryce	.27	.29	.34	.39	.55	.95	.23½	.31½	.38	.66	54.75	85 50	8.79	.05	37 052 60
Spaulding & Lenane	.42	.47	.62	.90	1.05	1 20	.18	.27	.33	.57	45 00	55.00	5.50	.12	45,672 50
B. J. Coyle	.37	.45	50	.56	.62	70	.33⅓	.50	.60	1.00	30.00	45.00	10.00	07	49,720.67
S. E. Babcock	.28	.33	.48	.60	.70	1.00	.25	.33	.38	.75	40.00	50 00	1.75	.07	39,043 70
Sloan & McIlvain	34	.41	52	.63	.74	.87	27	.34	.39	.59	25.00	50.00	8.00	.05	41,895.20
Sherman & McDonald	25	.36	53	.95	1.50	2 00	24	.31	.36	58	45 00	65.00	7.50	.20	45,404.60
W. E. Dean	.20	.40	60	1 10	1 25	1 50	.23	.33	.47	60	36 00	50.00	4.00	.10	39,993 80
B. Van Vranken	.13	.20	30	.35	.40	.50	.19	.26	.32	.55	30 00	35.00	6.00	.03½	25,369,10
J. McEneroe	.22	.28	.75	.85	.95	1 10	.17	.23	.27	.49	34.00	40.00	7.75	.08	34,323.20
S. V. Trull	.13	.16	.18	.20	.30	.38	.18	.30	.39	.50	40 00	30.00	1 50	.01	22,460.10
M. Nolan	.11	.26¼	.42½	.55	.82¼	.98	.16¼	.24½	.30	.58¼	37 27	44.00	5.00	.05½	27,179.32

in White, Romeyn, and Fonda Streets, South Avenue and Nott Terrace. On the eighteen-inch main in Fonda Street about two hundred feet of rock work was encountered, averaging about two and one-half feet deep. It was removed by the contractor at a cost of about ninety cents per cubic yard, and no extra allowance was made therefor.

The conditions found in Schenectady do not seem to be widely at variance with those ordinarily met with.

The contract was awarded to the bidder whose name appears twelfth in the schedule of bids, at the prices therein stated.

Ninety-seven per cent. of the work was completed within six working months.

The following is a detailed estimate of the work as finally completed, and represents the total cost of the work, exclusive of engineering, expenses of sewer commission, land damages, preparation of plans, records, etc.

EXCAVATION.

DEPTH.	FEET.	PRICE PER FOOT.	COST.
Less than 6 feet	14,509.2	$ .13	$1,886.20
6 to 8 feet	28,336.4	.20	5,667.28
8 " 10 "	5,186.1	.30	1,555.83
10 " 12 "	2,805.5	.35	981.92
12 " 14 "	1,395.0	.40	557.20
14 " 16 "	250.0	.50	125.00
16 " 18 "	50.0	1.00	50.00
		Total,	$10,823.43

PIPE FURNISHED AND LAID.

DIAMETER.	LENGTH.	PRICE PER FOOT.	COST.
6 inch,	202.0	$ .17	$ 34.34
8 "	38.254.0	.19	7,268.26
10 "	5.187.2	.26	1.348.67
12 "	5.487.3	.32	1,755.95
18 "	3.313.0	.55	1,822.15
		Total,	$12.229.37

ACCESSORIES.

24 Man-holes	@ $30.00	$ 720.00
4 Flush-tanks	@ 45.00	180.00
29 Flush-tanks	@ 40.00	1,160.00
137 Lamp-holes	@ 6.00	822.00
45.690.8 lineal feet repairing	@ .03½	1,599.18
6,593 B. M. Lumber	@ 20.00	131.86
Extras		210.65
Outlet		125.00
Iron Pipe laid		791.18
	Total.	$5.739.87

SUMMARY.

Excavation,	$10.823.43
Pipe and laying,	12.229.37
Accessories,	5,739.87
Total,	28,792.67

or a total cost, for construction proper, of $.55 per lineal foot.

The work afforded the contractor a reasonable profit, but it is doubtful if at present prices it could be duplicated. At the time bids were submitted common laborers could be hired at from one dollar to one dollar and twenty-five cents per day.

Prices of material were also depressed. The entire cost of the system, including man-holes, flush-tanks, and all accessories, all expenses of engineering, and preparation of plans and records, expenses of sewer committee, and all costs, of whatever nature, chargeable to the sewers, was $.72 per lineal foot.

A tax of $2.50 per capita on the population accommodated by these sewers, or a tax of one-half of one per cent. on the assessed valuation of the city, would have paid their cost.

The cost and extent of the Memphis sewers, to January, 1885, is summarized as follows in the Biennial Report of the Engineer and Superintendent of Sewers:

New Sewer Lines,	36.8 miles.	
Old Sewer Lines added,	4.1 "	
Sub-soil Drains,	35.6 "	
Flush-tanks,	192.	
Observation Openings,	342.	
Catch-basins,	5.	
Total cost of the Sewer System to date		$283,731.86
Cost per lineal foot of the new system, including sub-soil drains which were laid in the same trench,		1.46
Obstructions removed,	164.	
Cost of removal,		1,982.15
Average cost of each,		12.10
Cost of cleaning main sewer,		738.60

The following summary of the cost of a Separate System of Sewers in Keene, N. H., is given in a report on the practical operation of the Separate System of Sewers submitted to the New York State Board of Health by Horace Andrews:

The system comprises the following lengths of pipe:

	FEET.	
15 inch	9,065	Contract price, $2.05 per foot.
12 "	3,441	" " 1.61 " "
10 "	1,178	" " 1.34 " "
8 "	2,742	" " 1.06 " "
6 "	44,806	" " 90 " "
Aggregate length,	61,232	

The contract price given above includes all materials and expenses of laying.

There are forty-four flush-tanks, holding from 140 to 150 gallons of water, and capable of being discharged as often as once in six hours if necessary. Each flush-tank completed cost $63.00; they were built with double walls, having an air space between, to guard against freezing. Extra covers of wood have been provided within the iron covers, as an additional protection against frost. Two inlets allow the water of Beaver brook to enter one of the fifteen-inch mains. These inlets were built at a cost of $100 each. There are two outlets costing $200 each, and fifty man-holes costing $40 each.

The full amount paid by the city for plans, construction, superintendence, land damages, fees, etc., was $79,688.85, about $500 of which was paid for land damages, leaving the cost proper of the sewers, $79,188.85, or $1.29¼ per lineal foot.

Sub-soil drainage is secured by means of drain-tiles, nearly round and non-porous, laid in two-feet lengths.

The sewers are, in general, laid at a depth of six feet or more.

Examples of Cost Computed from Time Book.— Tables XVIII, XIX, XX and XXI were compiled by Mr. W. E. Ely, Assistant Engineer, Kalamazoo, Mich. They were computed from notes taken in actual work, and represent actual cost to the contractor. An allowance of ten or twenty per cent. above these prices would be proper in making preliminary estimates of cost. The soil was loam, sand, and gravel, and the roadway compacted gravel. The trenches were sheet piled the entire length.

TABLE XVIII.

Actual Cost of Labor and Material.

Size of Pipe.	Depth of Cut.	Cost of Pipe per foot.	Cost of Trenching and Back-filling per foot.	Cement.	Gaskets.	Laying Pipe.	Superintendence.	TOTAL.
		Cts.	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
10 inch	....	19	......	1.14	.60	4	......	......
12 "	....	29	......	1.55	.87	5	......	......
10 "	Under 6½ ft.	19	29.92	1.14	.60	4	9.0	63
10 "	6½ to 9 ft.	19	36.82	1.14	.60	4	11.0	72
10 "	9 to 12 ft.	19	*57.68	1.14	.60	4	15.5	87
10 "	12 to 15 ft.	19	46.70	1.14	.60	4	12.6	84

*Considerable water was encountered at this depth, which accounts for the increased cost of excavation.

Laborers' wages, $1.50 per day; superintendence, $10.00 per day. About one-sixth of the trenching was in water whose average static level was two feet above the grade line. The soil was of average compactness. The trenches were sheet piled nearly the entire length.

TABLE XIX.

Actual Cost of Labor and Material.

Size of Pipe.	Depth of Cut.	Cost of Pipe per foot.	Cost of Trenching and Back-filling per foot.	Cement.	Gaskets.	Laying Pipe.	Superintendence.	TOTAL.
		Cts.	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
6 inch	Under 6½ ft.	9	15	.54	.47	3	1.5	29
6 "	6½ to 9 ft.	9	21	.54	.47	3	4.0	38
6 "	9 to 12 ft.	9	28	.54	.47	3	7.0	48
6 "	12 to 15 ft.	9	*76	.54	.47	3	18.0	107
6 "	15 to 18 ft.	9	60	.54	.47	3	30.0	103
8 "	....	12	......	.77	.58	3	......	......
10 "	....	19	......	.84	.60	4	......	......
12 "	....	24	......	1.55	.87	5	......	......

* Considerable water was encountered at this depth, which accounts for the increased cost of excavation.

Laborers' wages, $1.50 per day; superintendence, $10.00 per day. Nearly all trenching was dry. The soil was rather favorable than otherwise, but required sheet piling.

TABLE XX.

Actual Cost of Labor and Material.

Size of Pipe.	Depth of Cut.	Cost of Pipe per foot.	Cost of Trenching and Back-filling per foot.	Cement.	Gaskets.	Laying Pipe.	Superintendence.	TOTAL.
		Cts.	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
8 inch	Under 6½ ft.	12	35	1.1	.58	3	9.83	61
8 "	6½ to 9 ft.	12	32	1.1	.58	3	8.00	56

Laborers' wages, $1.50 per day; superintendence, $10.00 per day. Water was found about one-fourth of the distance, but did not seriously retard the work. The soil was of average compactness.

TABLE XXI.

Actual Cost of Labor and Material.

Size of Pipe.	Depth of Cut.	Cost of Pipe per foot.	Cost of Trenching and Back-filling per foot.	Cement.	Gaskets.	Pipe Laying.	Superintendence.	TOTAL.
		Cts.	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
12 inch	Under 6½ ft.	26.25	18.0	3.45	1.16	4.40	11.8	65
12 "	6½ to 9 ft.	26.25	27.5	3.45	1.16	4.40	16.5	79
12 "	9 to 12 ft.	26.25	46.5	3.45	1.16	4.40	16.5	98
12 "	Over 12 ft.	26.25	76.5	3.45	1.16	4.40	29.5	141

Laborers' wages, $1.50 per day; superintendence, $10.00 per day. Much of the work was in wet trenches, requiring about

one man in every ten at the pump. In some of the deep trenching, the static level of the water was five feet above the grade line. The soil was tolerably compact, except where water was found, where there was quicksand.

Cost of Maintenance.—The total cost of removing obstructions in Memphis has been about one-fourth of one per cent. per annum on the cost of construction. Capitalized at six per cent. per annum, this amount represents approximately four per cent. of the cost of construction. In other words, the interest on four per cent. of the cost of the Memphis sewers invested at six per cent. per annum would have paid all costs of the removal of obstructions and cleaning of the sewers.

The cost of a semi-weekly inspection of the Separate System of Sewers at Kalamazoo, Mich., and the removal of all obstructions which have accumulated, for the past five years, has been less than $200 per year. The main sewers have never been cleaned except by the regular flushing, and upon taking out a section of the principal main this season the pipe was found in perfect order, with the exception of a thin coating of slime, which is always found adhering just at the water line, and which is continually being detached by its own weight and the current and swept away.

Sewer Assessments.—The following are some of the many plans adopted for assessing the cost of sewers:

1. By a general sewer tax, paying for the sewers as fast as they are built.
2. By issuing bonds and providing for their gradual payment by a general tax.
3. By assessing the property benefited.
4. By paying for the sewers by a general tax, and charging for permits to connect private drains.
5. By assessing the property adjoining the sewers in proportion to the frontage of each lot.
6. By assessing the adjoining property in proportion to the area of each lot.
7. By assessing the adjoining property in proportion to the value of each lot.
8. By assessing a certain part of the cost (varying from one-fourth to two-thirds) on the adjoining property in proportion to

the frontage (or area, or value), and raising the remainder by a general tax.

9. By assessing a certain uniform amount per foot front on adjoining property, and paying the remainder by a general tax.

The method of assessing the cost of a sewer upon "the property benefited" gives rise to perplexing questions. The judgement of different individuals will differ widely as to the limits of the district benefited, the proportion of benefit derived by each lot owner, and the relative value of the lots.

In assessing the cost of sewers in any section on the abutting property, a difficulty arises from the fact that some parts of any system will be much more expensive than others, and the extra cost will not be justly chargeable to the adjoining property.

In designing any system of sewers, the sewerage of a whole town, and the convenience of all the citizens, will require the construction of mains costing from two to four times as much as the laterals; and the conformation of the ground may necessitate much deeper cuts in some localities than in others. To compel the owners of the lots adjoining the mains and deep cuts to pay all the cost of them, when the extra cost is incurred to benefit distant territory, is a manifest injustice. The burden of the expense may be more nearly equalized, either by paying for the whole system by a general tax, or by assessing upon the lots a uniform amount per foot front (or in proportion to area, etc.), and paying for the remainder by a general tax.

To charge for connecting private drains with the sewers, more than a nominal fee to pay for inspection, is not advisable. The policy should be to encourage the citizens to use the sewers and abandon the objectionable methods for the disposal of sewage, which are employed where sewers are not used.

The most advisable method of sewer assessment to adopt in any place will depend upon the circumstances of the case. Among the most important considerations are the following: Whether the whole system of sewers is to be built at once or by piecemeal; whether there is to be one outlet or several,—that is, whether there are distinct sewer districts; the cost of the sewers, and the financial ability of the citizens.

Specifications and Drawings For Sewers

[ON THE SEPARATE SYSTEM].

THE SPECIFICATIONS and DRAWINGS which appear in this volume have been published in pamphlet form for use in actual work, and can be obtained by addressing

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